American POTATO JOURNAL

Volume 37 *December 1960* *Number 12*

CONTENTS

Official Publication of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY, U. S. A.

American Potato Journal

PUBLISHED BY

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, N. J.

Price $4.00 per year in North America; $5.00 in other countries.

Not responsible for free replacement of non-delivered or damaged issues after 90 days.

Second Class Postage Paid at New Brunswick, New Jersey.

SPROUTING, PLANT GROWTH, AND TUBER PRODUCTION AS AFFECTED BY CHEMICAL TREATMENT OF WHITE POTATO SEED PIECES.

III. COMPATIBILITY OF GIBBERELLIC ACID WITH CHEMICALS USED FOR SEED TREATMENT[1]

Herman Timm and Lawrence Rappaport[2]

Gibberellic acid (GA) has been reported to shorten the rest period of freshly harvested potatoes, to hasten sprouting and emergence (6, 7), and, under certain conditions, to increase tuber yields (9). Seed treatment with gibberellic acid, however, failed to hasten emergence in field experiments in 1956 and 1957 at Tulelake, California. Incidence of stem infection by *Rhizoctonia solani* Kühn was greater from treated seed than from untreated seed.

Gibberellic acid has not been found to affect the growth of fungi directly, nor is there adequate proof that it predisposes plants to fungous attack. Barton and Fine (1) found that gibberellic acid did not alter the fungicidal action of several materials used on tomato and bean plants. Rackham and Vaughn (5) stated, without presenting data, that bean plants sprayed with gibberellic acid without a fungicidal treatment had a slightly higher root-rot index than inoculated unsprayed control plants. Using a fungicide with GA reduced the incidence of root-rot.

Chemical treatment of whole potato seed is generally recommended as a control for *Rhizoctonia* (2, 3, 8), and supplemental treatment of the cut seed may be advantageous when planting is delayed by unfavorable weather (4). Since GA appears to be useful as a growth regulant for potato its effectiveness in hastening sprouting and emergence was determined with and without certain fungicides used for control of *Rhizoctonia.*

Materials and Methods

In two experiments, treatment action was measured in terms of plant emergence, seed piece decay, and stem infection. Seed pieces were classified as sound only if completely free of decay at the end of the experiment. The tubers used in both experiments were well-sprouted White Rose potatoes with sprouts removed. The use of sprouted seed ensured uniformity of seed materials.

The first experiment assessed the compatibility with GA of either cold formaldehyde or mercuric chloride ($HgCl_2$). Whole tubers, visibly free of sclerotia, were soaked five minutes in tap water or solutions containing GA (0.5 ppm), acidified $HgCl_2$, acidified $HgCl_2$ plus GA, cold formaldehyde, or cold formaldehyde plus GA. The air-dried seed was cut nad planted, 12 seed pieces per tray, three inches deep in moistened white sand. The trays, three per treatment, were placed in a room controlled at 68° F.

[1] Accepted for publication May 23, 1960. Appreciation is expressed to Merck & Co. and Abbott Laboratories, who generously provided financial assistance.

[2] Assistant Olericulturists, Department of Vegetable Crops, University of California, Davis, Calif.

A second experiment determined the compatibility of GA with fungicides used for supplemental treatment of cut seed. Whole tubers heavily infested with *Rhizoctonia* sclerotia were divided into two lots. One lot was soaked five minutes in tap water or solutions containing GA (1 ppm), acidified $HgCl_2$, or acidified $HgCl_2$ plus GA, and was then air-dried, cut, and planted. The second lot was soaked five minutes in acidified $HgCl_2$, air-dried, cut, and then dipped briefly in one of the following solutions: tap water, GA (1 ppm), acidified $HgCl_2$, Semesan Bel (hydroxymercurinitrophenol 12.5% and hydroxymercurichlorophenol 3.8%), Captan 75 (*N*-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide 75%), or Phygon XL (2,3-dichloro-1,4-naphthoquinone 50%). The seed-disinfecting chemicals were applied according to manufacturers' recommendations. The repeat treatment applied to the second lot is not recommended, but was included to assess the effectiveness of GA as a growth stimulator in the presence of excess fungicide.

In a greenhouse held at 50-60° F, seed was planted four inches deep in a soil bed previously sterilized with methyl bromide. Ten seed pieces per treatment were planted in a randomized block design with four replications.

Results and Discussion

GA, applied separately or in combination with several fungicides, generally hastened emergence. Treatment with cold formaldehyde or $HgCl_2$ alone retarded emergence at first (Figs. 1, 2). Adding GA to $HgCl_2$ or to cold formaldehyde consistently accelerated emergence from *Rhizoctonia*-free seed (Fig. 1). $HgCl_2$ treatment of *Rhizoctonia*-infected seed delayed emergence 14 days, but it then proceeded rapidly (Fig. 2). Emergence for $HgCl_2$ plus GA was the same as for GA or water for the first two weeks, and then was faster. Injury to the developing buds undoubtedly caused the early inhibition of sprouting and emergence by $HgCl_2$ or cold formaldehyde. Other differences in emergence, as shown in Figs. 1 and 2, are likely attributable to differences in soil temperature and depth of placement of seed.

Treatment with $HgCl_2$, alone or in combination with GA, essentially prevented stem infection by *Rhizoctonia* (Table 1). Plate culture studies of sclerotia from $HgCl_2$-treated seed revealed that the organism had been killed.[3]

Differences in *Rhizoctonia* infection of stems may explain why emergence of seed treated with $HgCl_2$ was retarded at first and then surpassed that of seed treated with GA or water (Fig. 2). Although $HgCl_2$ was toxic to the more advanced buds, new buds elongated, essentially free of *Rhizoctonia* infection. Stems of both GA-treated and water-treated seed were severely infected (Table 1), and emergence lagged until new eye or axillary buds elongated. The percentage of infected plants was slightly higher from GA-treated seed than from water-treated seed. *Rhizoctnoia* frequently killed the first shoot, and the addition of GA stimulated lateral extension. GA promoted elongation of new buds and partially overcame the toxic effects of $HgCl_2$. Clearly, the extent of initial infection by

[3]The authors thank L. J. Petersen, Laboratory Technician of the Department of Plant Pathology, for help with this phase of the investigation.

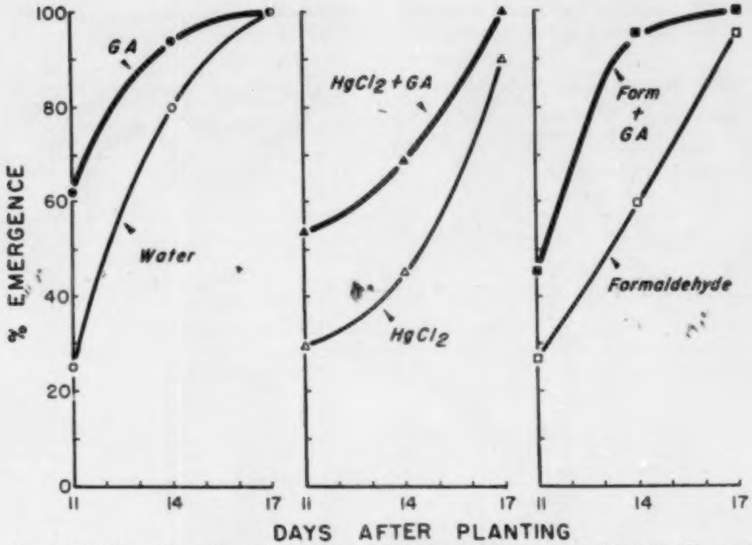


Fig. 1.—Effect of whole seed treatment with GA (0.5 ppm), acidified $HgCl_2$, and formaldehyde on emergence of White Rose potato plants.

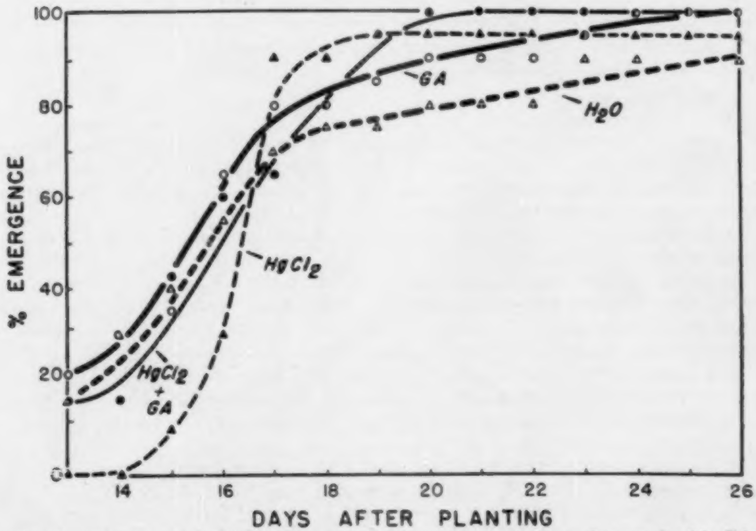


Fig. 2.—Emergence of White Rose potato plants from whole seed treated with GA (1 ppm) and acidified $HgCl_2$, separately and in combination.

TABLE 1.—*Effect of seed treatment on condition of seed piece, stem count, and stem infection of White Rose potatoes by Rhizoctonia 26 days after planting.*

Seed	Chemical treatment	Per cent Seed Pieces With Decay	Number Stems Emerged Per Seed Piece	Per cent Stems Infected With Rhizoctonia
Whole	Tap water	3.0	2.2	53.4
	GA (1 ppm)	3.0	2.3	64.4
	$HgCl_2$	7.0	2.4	2.1
	$HgCl_2$ + GA	0.0	2.7	0.0
	L.S.D. 5%	N.S.	N.S.	–
(Whole seed treated with acidified $HgCl_2$ prior to cutting)				
Cut	Tap water	6.7	2.1	
	GA (1 ppm)	0.0	2.7	
	$HgCl_2$	50.1	1.5	
	$HgCl_2$ + GA	25.0	1.9	
	Semesan Bel	13.9	1.3	
	Semesan Bel + GA	16.4	2.0	
	Captan	1.1	2.3	
	Captan + GA	18.9	2.3	
	Phygon	6.7	2.4	
	Phygon + GA	14.1	2.4	
	L.S.D. 5%	8.8	0.7	
	1%	16.1	1.1	

For statistical analysis original percentages were transformed to angles by using formula: Angle = Arc Sin $\sqrt{\text{percentage}}$.

Rhizoctonia strongly conditions the response in sprouting and emergence to $HgCl_2$ plus GA, or GA alone. It also suggests that the failure of GA-treated seed to emerge earlier than untreated seed, as in field plantings at Tulelake, was due to *Rhizoctonia* infection.

In the second experiment, using seed severely infected with *Rhizoctonia* sclerotia, initial whole-seed treatment with $HgCl_2$ was so effective that stems from retreated seed pieces had less than 3 per cent infection. Individual data are not presented. It is interesting, both in field observations at Tulelake and in the second experiment (Table 1), that *Rhizoctonia* infection was somewhat greater in plants from GA-treated seed. Although GA has not been shown to affect the growth of fungi, it might be interesting to re-examine the response of strains of *Rhizoctonia* to GA. An alternate possibility is that susceptibility to infection was increased by the treatment.

Supplemental treatment of cut seed with Phygon, captan, or mercury-base compounds, especially $HgCl_2$, increased seed piece decay (Table 1). This was reflected in slow emergence (Fig. 3) and fewer stems per hill. The cause was undoubtedly injury of tissue by excessive $HgCl_2$. Including GA with $HgCl_2$ markedly reduced the severity of seed piece decay. GA,

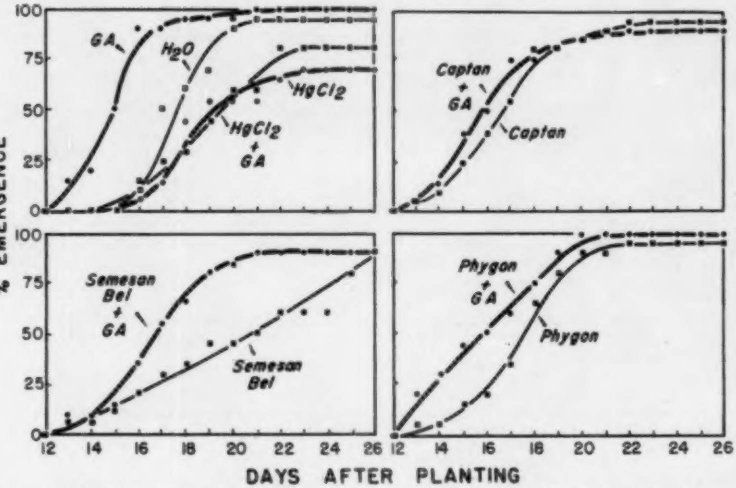


Fig. 3.—Plant emergence after White Rose potato seed were dipped for five minutes in acidified $HgCl_2$, air-dried, and then cut and retreated with the indicated fungicide.

applied together with supplemental treatments, tended to increase the percentage of seed piece decay. Seed piece decay was especially increased when GA was included with captan. The explanation is not known.

Summary and Conclusions

GA promotes sprouting and earlier emergence of potato seed pieces disinfected by a number of fungicides used for surface treatment. In general, the chemicals retarded emergence, but adding GA hastened emergence. Emergence after treatment with GA, separately and together with $HgCl_2$, varied in the presence and absence of seedborne *Rhizoctonia.* Stem infection by *Rhizoctonia* was severe following GA or water treatment, but absent following $HgCl_2$ treatment. Treating whole tubers with $HgCl_2$ was as effective as a supplemental treatment of cut seed with Semesan Bel, captan, or Phygon, all of which prevented stem infection. Only retreatment with $HgCl_2$ increased seed-piece decay.

After initial whole-seed treatment with $HgCl_2$, applying GA to cut seed along with various fungicides tended to increase the percentage of seed pieces with decay unless the second treatment was with $HgCl_2$. The number of stems per seed piece was essentially unaffected by GA.

GA promotion of sprouting and early emergence was not affected by the fungicides used. Grower objections to mercuric chloride arise from its toxic effect on seed pieces. GA, therefore, besides affecting rest period, may have commercial value in overcoming early inhibition of growth by chemicals like $HgCl_2$.

The desirability of using a fungicide, such as mercuric chloride, with GA on seed potatoes is emphasized.

Literature Cited

1. Barton, L. V., and J. M. Fine. 1958. Non-interference between effects of gibberellic acid and fungicides. Contrib. Boyce Thompson Inst. 19(3): 291-294.
2. Davis, G. N. 1949. Growing potatoes in California. Calif. Agr. Ext. Ser. Cir. 154.
3. Dykstra, T. P. 1941. Potato diseases and their control. U.S.D.A. Farmers' Bull. 1881.
4. Oswald, J. W., D. H. Holland, and T. Lyons. 1958. Potato "seed" treatment. Calif. Agr. Ext. OSA 20.
5. Rackham, R. L., and J. R. Vaughn. 1959. The effects of gibberellin and fungicide on bean root rot. Pl. Disease Reptr. 43(9): 1023-1026.
6. Rappaport, L., L. F. Lippert, and H. Timm. 1957. Sprouting, plant growth, and tuber production as affected by chemical treatment of white potato seed pieces. I. Breaking the rest period with gibberellic acid. Am. Potato J. 34: 256-260.
7. Rappaport, L., H. Timm, and L. F. Lippert. 1958. Gibberellin on white potatoes. Calif. Agr. 12: 4-5, 14.
8. Simpson, G. W., and W. A. Shands. 1949. Progress on some important insect and disease problems of Irish potato production in Maine. Me. Agr. Expt. Sta. Bull. 470.
9. Timm, H., L. Rappaport, P. Primer, and O. E. Smith. 1960. Sprouting, plant growth, and tuber production as affected by chemical treatment of white potato seed pieces. II. Effect of temperature and time of treatment with gibberellis acid. Am. Potato J. 37: 357-365.

SOIL COMPACTION AND POTATO GROWTH[1]

G. R. BLAKE, D. H. BOELTER, E. P. ADAMS, J. K. AASE[2]

Potatoes are known to be quite sensitive to soil physical condition (3). Furthermore, potatoes are one of our most intensively tilled crops. Tillage, planting, spraying and harvest operations—often appearing necessary when soils are wet and most subject to compaction—contribute to a soil structure problem in potato fields that is likely to affect yield (1). Most studies, however, show little information concerning the effects of compaction on such factors, as tuber set, plant vigor or quality.

Studies were made in 1955, 1957 and 1958 to determine the effects of soil compaction on growth and development as well as on the yield of potatoes. The method was to effect deliberate packing at the beginning of the season such as might occur in excessive seedbed preparation.

MATERIALS AND METHODS

Plots were established on Bearden silty clay loam in the Red River Valley of Minnesota. This soil is a lake-laid, calcium carbonate Salonchak with a very high organic matter content (8.5%) and pH of 7.6. It is a commonly used soil for potatoes in this area.

Treatments consisted of surface packing vs. no packing after seedbed preparation and before planting. Plots were replicated six times. Planting, tillage and harvesting were done with conventional field implements.

Packing was done in 1955 by running a tractor back and forth across the plots in order to cover the complete soil surface. The static weight of the rear wheels was about 2800 pounds. This gave approximately 15 pounds per square inch pressure imposed in 1956. In 1957 a partly loaded truck with a rear axle load of 15,000 pounds was used for packing. Twice over the whole plot surface gave a packing much more like one would expect from several trips with lighter equipment such as a tractor and disc. The actual pressure in packing was between 60 and 140 pounds per square inch depending on the estimated bearing area of the wheels.

A uniform fertilizer treatment was made according to experiment station recommendations.

The same plots were packed each year. The crops, however, were rotated. Potatoes followed sugar beets in a rotation of potatoes, sweet clover, clover-fallow, and sugar beets. Pontiac and Early Gem were the varieties grown.

RESULTS AND DISCUSSION

Extent of packing as shown by soil measurements:

Despite the relatively light packing in 1955, there were significant

[1]Accepted for publication June 2, 1960. Paper No. 4405, of the Scientific Journal Series, Minnesota Agricultural Experiment Station. This study was supported in part by NC-17 Regional Research Funds.
Acknowledgment is made to the American Crystal Sugar Company for use of land and care of the crop. Thanks are also expressed to Professor C. J. Eide and his assistants of the Univ. of Minn. Plant Pathology department, for scab and scurf ratings.
[2]Associate Professor of Soils, and former Research Assistants, University of Minnesota, St. Paul, Minn.

effects on penetrability to a depth of at least 12 inches when measured in August.

With more severe packing in 1957 and 1958, several soil properties were measured on adjacent wheat plots, packed the same as potato plots. Bulk densities showed differences of 1.02 vs. 1.17 and 1.06 vs 1.16 between non-packed and packed plots in the two years. These differences were highly significant. Air permeability was only 23% as great on packed plots in 1957. Also a highly significant increase in penetrability occurred from packing in both years. This extended to at least the 10 inch depth measured.

Perhaps the most important indication of poor soil condition for potatoes was the low air porosity on packed plots. Determinations were made on cores removed, soaked and drained at 60 cm. tension to remove water from easily drained pores. Results are shown in Table 1. A tentative threshold value for limiting soil aeration based on diffusion measurements has been set between 10 and 15% air space (2, 7). With this as criterion, potatoes on packed plots might be expected to have suffered severely in growth particularly after rain when pore space approached the 8 to 9% shown in Table 1.

There is a question whether these data from wheat plots are applicable to ridged potatoes. The potato ridge undoubtedly has higher porosity and lower bulk density than the under-ridge environment. It has been pointed out that the ridge may partially compensate for the less desirable environment deeper in the soil on packed plots (1). However, the under-ridge soil would be made even more dense by cultivating. Even though a few inches of soil in the ridge probably was very porous, the root system itself may have been subjected to even lower air porosities than shown in Table 1.

Potato stand, vigor and yield:

Potato stands were measured by counting hills in 1955 and 1958. Significant differences were not found.

A difference in the vigor of individual plants caused by the treatments was, however, very noticeable. On packed plots emergence was slow and plants were much less vigorous throughout the whole season. It is not known whether the principle damage to vigor occurred as a result of slow emergence, or whether there was a prolonged aggravation during the growing season on packed plots..

Mild packing in 1955 gave a significant yield reduction in U. S. No. 1 Pontiac potatoes of 25%. The Early Gem variety was included in 1958 in the belief that it might be more sensitive to adverse soil physical conditions. Yields for 1957 and 1958 are shown in Table 2. The 1957 difference in yield was not statistically significant. In 1958, yield differences were highly significant for both varieties.

The effect of soil packing on yields was a secondary concern of this study. Yield reductions from packing would be expected. However, packing in these experiments probably represented a more severe treatment than one would expect on a well managed farm.

The fact that packing did not significantly affect yield in 1957 suggests that conditions that might limit yields in one year may not necessarily apply in all years.

TABLE 1.—*Easily drained pore space (air space at 60 cm tension) measured in surface packed and non-packed plots.*

Year	Packed	Not packed
1957	8.4	14.9**
1958	9.4	13.6**

*Differences highly significant.

TABLE 2.—*Potato yields as affected by soil packing in bushels per acre of U. S. No. 1 size.*

Year	Packed	Not packed
1957 Pontiac	186	165
1958 Pontiac	342	75*
1958 Early Gem	219	52*

*Differences highly significant.

Compaction and tuber set, shape and specific gravity

In 1958, careful measurements were made of depth of potato tubers at harvest. Care was used to level the soil surface before measurement in order to use the original soil surface as a benchmark. The center of tuber depth in 30 hills was measured on each treatment. It was found that tuber depths averaged 2.85 and 3.70 inches in packed and non-packed plots, respectively. The difference of nearly 1 inch was significant at the 5% level. It should be noted that with the ridge in place, tuber depth from the ridge top would have been 2 to 3 inches greater.

There are two possible reasons for the shallower tuber depth under packed plots: 1) Packing discouraged deep rooting and tuber set; 2) Seedpiece depth varied. Depth of planting has been shown to affect depth of tubers only slightly (5). Furthermore particular care was excercised in planting to avoid this. It is therefore believed that the difference found was caused by compaction effects on rooting depth.

Counts of all tubers, regardless of size, were also made to determine whether yield differences were due to tuber set or tuber growth. A significant difference in numbers was not found. The average size of all tubers greater than one-half inch diameter was 1.4 and 2.0 inches for packed and non-packed plots, respectively. The weight of potatoes less than 2 inches was equal on both treatments (approximately 17 bu./A.) but was a greater percentage of the total in the packed plots. Therefore, one may conclude that tuber growth, rather than tuber set, caused the yield difference.

The specific gravity of potato tubers was found to be lower on packed plots during the two years it was measured. In 1958 when two varieties

TABLE 3.—*Compaction and tuber specific gravity.*

Year and variety	Packed	Not packed
1957 Pontiac	1.057	1.061
1958 Pontiac	1.068	1.078
1958 Early Gem	1.078	1.084

Differences significant at 5% level in 1957 and at 1% level in 1958.

were grown, both showed lower values due to packing. These data showing marked differences, are presented in Table 3. Although differences were significant in 1957, they may not have been great enough to be of practical consequence.

A possible reason for the differences found in specific gravity is that soil and plant temperatures were likely to be higher during tuber formation in packed soils. It is well known that this could affect specific gravity of tubers (6). There are three reasons for postulating higher daytime soil temperatures on packed soil. First, there was less luxuriant foliage on packed soils. This would be expected to result in higher temperatures in the soil as well as around the plant itself during the day. Second, the heat conductance of soil increases with soil bulk density. The daily maximum temperature in such soils would, therefore, be expected to be higher, (8). Third, it has already been pointed out that potato tubers were nearer the soil surface at harvest. The soil temperature profile is such that its daytime temperature is higher nearest the soil surface.

Of course, the influence of night-time temperatures on potato growth should not be ignored. Without supporting data, however, it is more difficult to postulate the effect of treatment on night-time soil temperatures. Temperature differences between treatments would be expected to be less than for day-time readings.

As Murphy & Goven (6) point out, any difference that changes the physiological maturity of potatoes at harvest may affect the specific gravity of the tubers. Delayed emergence or other effects could cause the differences found if viewed in this perspective. The effect of soil density itself should not be overlooked as a possible cause of lower tuber specific gravity.

No difference was found in percentage of mis-shapen potatoes caused by treatment. There was a higher percentage of mis-shapen Early Gems than of Pontiacs, however.

Effect of packing on scab-and silver scurf:

Samples of potatoes from all plots were examined for scab and silver scurf after harvest. Differences between treatments were very small and did not prove to be significant. These observations were carried out only in 1958. Conclusions from this single year must be regarded as tentative.

SUMMARY

Bearden silty clay loam, a typical potato soil in the Red River Valley in Minnesota, was deliberately surface packed after seedbed preparation

and before planting to observe its effects on potato growth and development. Observations were made in 1955, 1957 and 1958 with the following results:

1. Packing treatments affected penetrability to the 12 inch depth measured. Average bulk density was increased from 1.04 to 1.17, during two years.

2. Easily drained pore space (air space at 60 cm tension) was reduced to approximately 9%, a value believed to be less than the threshhold value for adequate soil aeration.

3. Emergence of seed pieces was delayed, plant vigor was greatly reduced and yield lowered two of three years by soil packing. The number of hills at harvest was unaffected by treatment.

4. Tubers set an average of about 1 inch nearer the soil surface on packed plots. The number of tubers set and percentage of mis-shaped tubers were the same for both treatments.

5. Specific gravity of tubers was higher on non-packed plots. This is believed to be caused by lower soil temperatures near the soil surface, greater tuber depth, better aerial canopy, or to some other factor that affected physiological maturity at harvest time.

6. Soil packing did not affect scab or silver scurf in the one year these diseases were observed.

Literature Cited

1. Blake, G. R. and R. J. Aldrich. 1955. Effects of cultivation on some soil physical properties and on potato and corn yields. Soil Sci. Soc. Am. Proc. 19: 400.
2. Blake, G. R. and J. B. Page. 1948. Direct measuremet of gaseous diffusion in soils. Soil Sci. Soc. Am. Proc. 13: 37.
3. Bushnell, John. 1953. Sensitivity of potatoes to soil porosity. Ohio Agr. Expt. Sta. Res. Bull. 726. See also Am. Potato J. 33: 204, 1956, and Am. Potato J. 33: 242, 1956 for continuation of Bushnell's work.
4. Lorenz, O. A. 1950. Air and soil temperatures in potato fields, Kern County, California during spring and early summer. Am. Potato J. 27: 396.
5. Mowisi, M. A. 1953. The effect of depth of planting on germination, level of tuber formation and yield of the potato crop. Am. Potato J. 30: 243.
6. Murphy, Hugh J. and Michael J. Goven. 1959. Factors affecting specific gravity of the White Potato in Maine. Maine Agr. Expt. Sta. Bull. 583.
7. Wesseling, J. and W. R. van Wijk. 1957. Soil physical conditions in relation to drain depth. In *Drainage of Agricultural Lands*. Agron. Monogr. VII. J. N. Luthin, editor.
8. Wollny, E. 1879, 1882. Untersuchungen uber die Temperatur des Bodens im dichten und im lockeren Zustande. Forschungen auf dem Gebiete der Agrikultur—Physik 2:133; 5:34.

RELATION OF POTATO TUBER GROWTH AND SKIN MATURITY TO INFECTION BY COMMON SCAB, *STREPTOMYCES SCABIES*[1]

W. J. Hooker and O. T. Page

Infection of potato tubers by *Streptomyces scabies* (Thaxt.) Waksman and Henrici usually occurs before or during enlargement of the tuber. A method has been described (Hooker, 6) for direct observation of potato tubers during the growth and expansion phase. A preliminary report of observations on the sequence of scab lesion initiation and tuber enlargement has been presented in abstract (Hooker and Page, 7). Thaxter (18) demonstrated wound infection of tubers by *S. scabies*. He suspected that a tuber had to be growing for normal scab development. He uncovered growing tubers, inoculated them, and by means of a glass plate kept soil from the tuber surface. The glass plate was covered with soil and observations were made at intervals. He also observed that infection of very young tubers, ¾ of an inch or less in length, occurred at any point on the surface without reference to lenticel or wounding. Wolenweber (19) observed that actinomycosis of the potato is primarily a disease of the growing tuber and not of the storage tuber. Sanford (15) studying the relation of soil moisture to scab infection reported a critical period for susceptibility in the growth of the tuber, after which very little scab infection took place. Fellows (3) in 1926, first demonstrated the relation between scab infection and tuber expansion by introducing inoculum into soil in which potatoes were actively growing. His observations on the sequence of infection and scab lesion development were made after the tubers had been harvested. He demonstrated that growth and disease were coincidental and that tubers which were not growing were not infected. Jones (9) concluded that potato tubers were susceptible up to the stage when their tissues were not completely protected by a well suberized barrier. Richardson (14) observed scab lesion development only in areas of tuber enlargement, and that scab severity varied directly with tuber growth. Lawrence (10) reported scab lesion development on detached small tubers 1 week after inoculation.

Materials and Methods

The role of tuber skin and underlying tissue in resistance of tubers to scab, was evaluated using 2 mm slices of tissue either from the surface or from the center of the tuber. Tubers from 14 potato varieties representing varying degrees of resistance to scab were obtained from a uniform trial on the organic soils of northern Iowa. Before slicing, all tuber surfaces were washed under running tap water. One group was autoclaved for 15 minutes, and a second group was disinfected by 48 hours fumigation with propylene oxide. Skin surfaces of a third group were washed gently with detergent (Tide) and rinsed thoroughly under running water without surface disinfection and finally rinsed with sterile distilled water. Slices

[1]Accepted for publication June 27, 1960. Journal Paper No. 2643 of the Michigan Agricultural Experiment Station, East Lansing, Michigan and Journal Paper No. J3933 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1184.

from the center of the tuber were washed under running tap water and rinsed in sterile distilled water. Tuber slices were inoculated by spraying with a suspension of spores using a DeVilbiss atomizer.

Observations of growing tubers were made using the method of Hooker (6) which consisted of growing a potato plant in an inverted 8″ pot wth a 3″ hole cut in the side. Seed of the Cobbler variety was surface disinfected using the hot formaldehyde method and sprouted in quartz sand. Quartz sand was used to fill the pot to approximately 1 inch below the lower level of the hole, and the stem of the potato sprout was oriented so that it grew upward through the 0.5 inch hole normally situated at the bottom of the pot. Manipulations and observations of growing tubers were made through the lateral 3 inch hole. This hole was plugged and the entire pot covered with Sphagnum moss. Once a week the pot was flushed thoroughly with water and nutrient solution (Smith and Walker 17) was poured over the sand.

Growing tubers were inoculated with spore suspensions of *S. scabies* obtained from petri plate cultures of isolates 9 (Hooker, 5). Spores from 4 plates were suspended in approximately 25 ml. of water, filtered through cheese cloth, and sprayed on tuber surfaces with a DeVilbiss atomizer under low pressure. Extreme care was taken to avoid mechanically injuring tuber surfaces during inoculation. Tubers were photographed at weekly intervals and observations were supplemented by drawings of certain tubers. The relationship between tuber enlargement and scab lesion development as well as the sequence of scab lesion development was recorded. Growth patterns of developing tubers were determined by painting the tubers with India ink. In certain instances, tubers were inked and later inoculated with spores of *S. scabies*.

Experimental Results

S. scabies grew well producing abundant aerial mycelia and spores on tuber disks free of skin cut from the the center of tubers of varieties which were either susceptible or resistant to scab and which had been killed either by autoclaving or fumigating with propylene oxide (Fig. 1). In contrast, aerial mycelium was very sparse on similar tuber disks which had only been washed. Apparently normal wound healing activity prevented to a great extent the growth of *S. scabies* on the cut surface.

No macroscopically visible growth of *S. scabies* developed on unbroken skin surfaces of either resistant or susceptible varieties regardless of the treatment used for reducing surface contamination. Abundant growth of *S. scabies* developed in certain areas where the skin had been abraded and the interior tuber tissue exposed during preparation for autoclaving or fumigating.

There was no correlation between varietal resistance and ability of *S. scabies* to grow on cut tuber surfaces after any treatment. Susceptible varieties used in the trial were Cobbler, Katahdin, Pontiac, Pawnee, Chippewa, Triumph, and Red Warba. Sebago as intermediate in resistance and highly resistant varieties were Ontario, Cayuga, Menominee, Russet Burbank, Yampa, and U.S.D.A. seedling clone B116-13.

Potato plants were grown in inverted 8-inch pots in 3 different trials and tuber infection was essentially similar. Plants grew well (Fig. 1A)

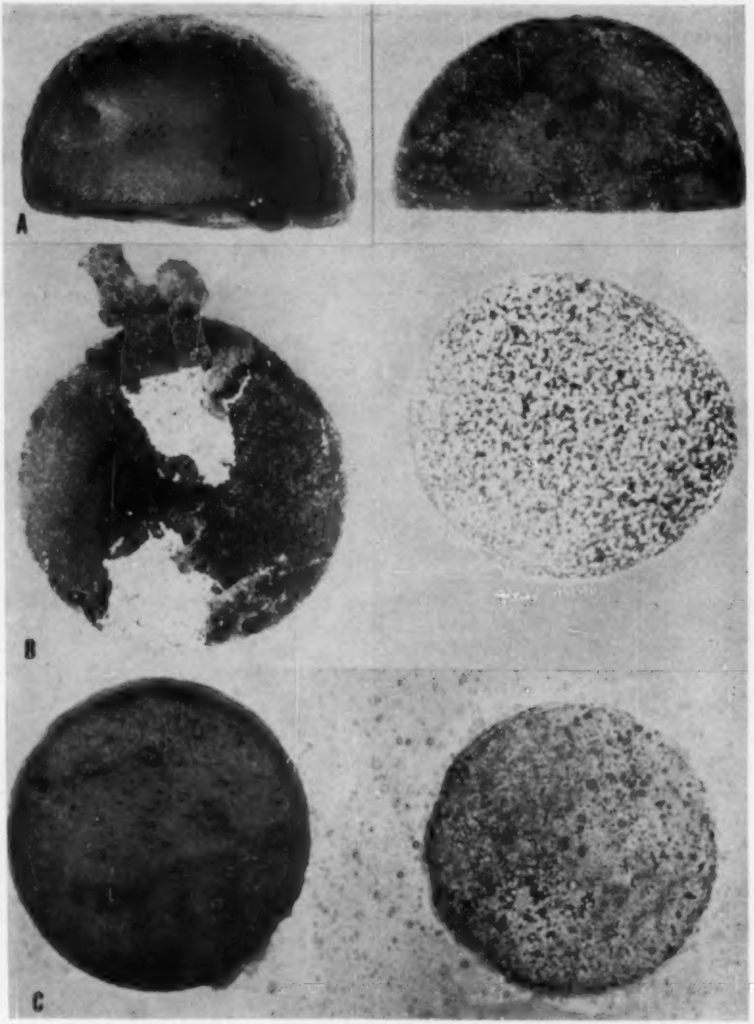


FIG. 1.—Disks (18 mm in diameter) from tuber tissue of susceptible potato varieties which had been inoculated by spraying with a spore suspension of *S. scabies* after: A, thorough washing of the disc surface in running tap water (17 days incubation); B, fumigation with propylene oxide (3 days incubation); and C, autoclaving on a glass slide for 15 minutes at 15 lbs pressure (3 days incubation). Discs at the left were from the skin surface of mature tubers and those at the right were from the center of the tuber.

and although tubers developed satisfactorily they did not attain large size. In all, records were available from at least 50 pots. Observations were not satisfactory in a number of these pots due either to adverse orientation of tubers within the pot or because certain tubers developed rapidly under the sand and those above the sand failed to enlarge.

A representative series of photographs is shown (Fig. 2B-F). Two days after photographing (Fig. 2B), tubers were inoculated by gently spraying with a spore suspension. Photographs were made at weekly intervals following inoculation. One week ofter inoculation (Fig. 2C) (9 days after photograph, Fig. 2B) practically all tubers had enlarged to some extent. Some cortical necrosis was suggestive of scab on the roots but there was no scab which could be positively identified as such on the tubers. Scab was evident 14 days after inoculation (Fig. 2D) as punctate necrotic spots which were situated in a circular manner around the apex of enlarging tubers.

Tuber 1 which was enlarging more rapidly than the others, first developed a ring of punctate necrotic spots. In 14 days (Fig. 2D), these had coalesced to form a ring of necrotic tissue with aerial hyphae of *S. scabies* on the surface. Three weeks after inoculation (Fig. 2E), tuber growth was apparently restricted in the area of deep scab and the apex of the tuber had become somewhat raised. Although the tuber continued to enlarge slightly, scab did not progress much further. The apical end of this tuber is shown (Fig. 3A) 35 days after inoculation.

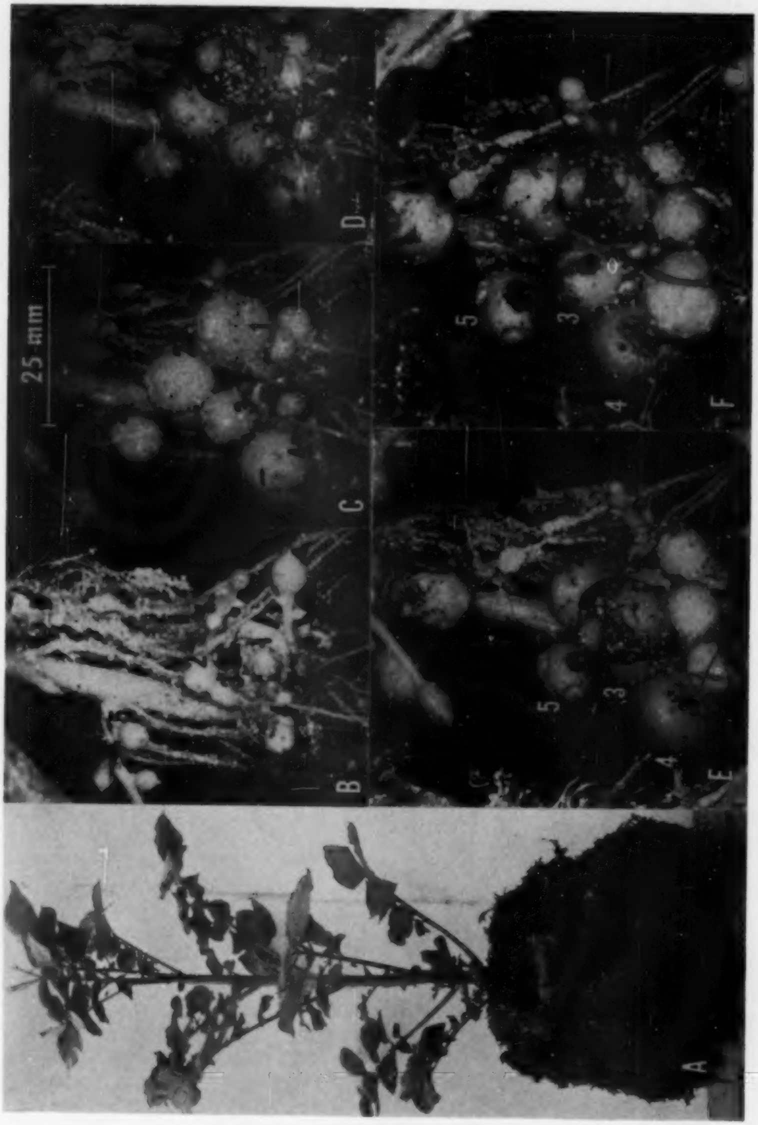
Tubers 2, 3, and 4 enlarged somewhat less rapidly than tuber 1 and the rate of scab development was also less rapid. Fourteen days after inoculation (Fig. 2D), these tubers had developed punctate necrotic spots approximating a circular arrangement around the apex and at the close of the trial, 35 days after inoculation, all had well developed more or less continuous necrotic rings around the apex.

Tuber 5 (Fig 2E), 21 days after inoculation, had developed a ring of necrotic spots around the growing point. Although the tuber had enlarged slightly 35 days after inoculation, it remained essentially unchanged (Fig. 3B).

Scab first developed around the apex but toward the close of the observation period, scab occasionally developed on other portions of the tuber, (Fig. 2F, tubers 3, 4, and 5). These scabbed areas are believed to have resulted from wound infection associated with manipulations during observation and culture. Lesions of this type were never observed early in the observation period.

A well defined ring of scabbed tissue around the growing point (Fig. 3C) usually developed after a number of punctate necrotic infections had coalesced. Occasionally tubers became irregular in shape when necrosis was deep. In a rapidly growing tuber the apical portion apparently developed so rapidly that scab did not grow laterally over the apex. However, when the tuber was infected but not expanding rapidly or when inoculation was repeated, necrosis often involved the entire apex.

In the Cobbler variety, tuber expansion as determined by inking unexpanded tubers, was most rapid at the apex (Fig. 3D and E) with the area near the stolon attachment growing slowly. Areas of expansion around the eyes (Fig. 3D) were less frequently demonstrated. Relatively


25 mm
A
B
C
D
E
F
5
3
4
5
3
4

slow growing tubers which were usually longer than thick, expanded similar to that of Fig. 3F.

The sequence of tuber enlargement followed by scab infection was demonstrated by inking tubers. After a few days, those rapidly expanding could be identified. Such tubers, when inoculated, developed a circular pattern of scab lesions in the new (uninked) tissue surrounding the tuber apex and outside the margin of the inked area (Fig. 3G,H,I, and J).

Tuber expansion under severely scabbed areas was often retarded and tubers became somewhat misshapen. When tuber expansion continued under extensively scabbed areas, growth was irregular and new tissue forming between the scabbed areas was likewise scabbed (Fig. 3K).

Tubers were formed approximately 2 months after seed was planted and about 1 month after plants were placed in the observation pot. Most but not all tubers were formed within a period of 10-20 days, although throughout the period of observation new tubers developed.

After a tuber was formed, no matter how small, it remained on the stolon tip until removed for observation. In the limited number of observations in these trials, no tubers 1 cm. or more in diameter were resorbed or reduced in size.

Even though a number of tubers were present on a plant, growth was most rapid in a few tubers whereas other tubers remained relatively unchanged in size.

Roots did not grow profusely in the space above the sand. Those which were present developed a tan cortical discoloration typical of scab infection within 10 to 14 days following spray inoculations but roots did not rot further.

Necrosis of stems was typically a tan flecking apparently the result of lenticel invasion. Lesions were lenticular in shape, 2-4 mm. long, and light brown to tan in color. They developed within 2 weeks after inoculation and in certain instances were so abundant that they almost covered the stem surface. Lenticel lesions were similar to those shown by Hooker et al, Fig. 1E (8). Deep cortical stem lesions were lacking and only occasionally were circular lesions formed which resembled typical tuber lesions.

Discussion

Jones (9) demonstrated that *S. scabies* could not penetrate normal barriers of wound cork composed of well suberized cells. He obtained plentiful growth of *S. scabies* on cut tuber surfaces under which a 3-5 cell

Fig. 2.—A, potato plant growing in an inverted 8-inch pot modified for tuber observation.

B-F, a series of photographs taken at weekly intervals illustrating the relationship between tuber enlargement and scab development.

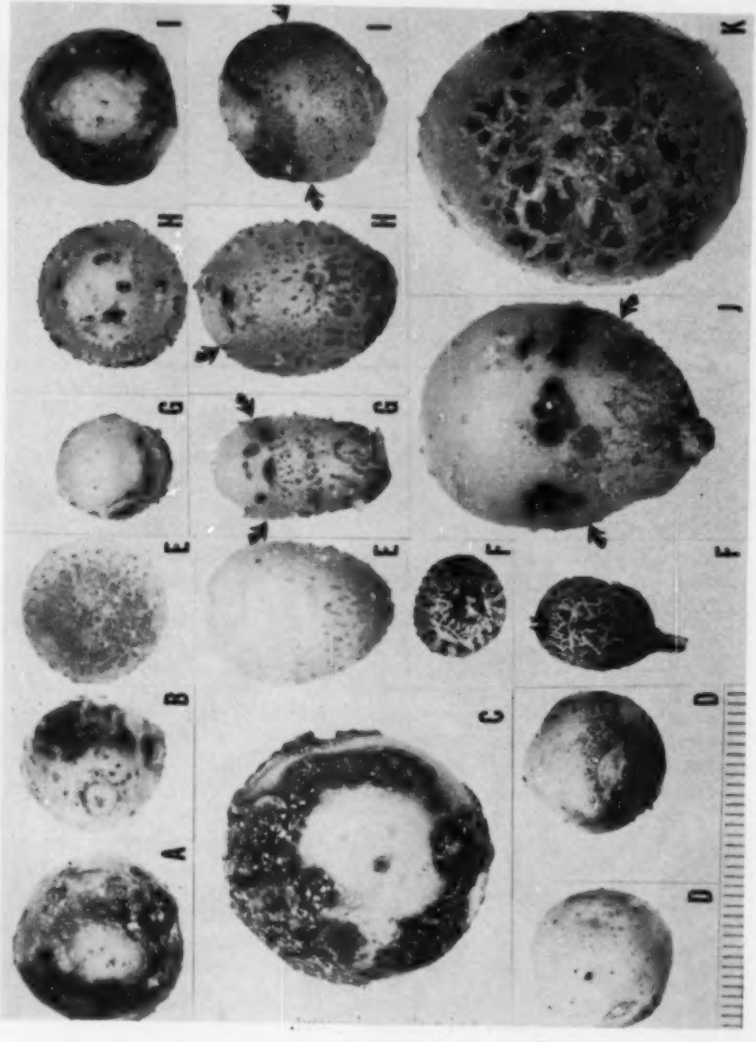
B, tubers 2 days before inoculation.

C, tubers of the same plant 1 week after being inoculated by spraying with a spore suspension of *S. scabies*. Note absence of macroscopically visible scab lesions.

D, tubers 14 days following inoculation. Note enlargement of tubers, the development of scab lesions, and the lack of lesions in the extreme center of the apex of tuber 1.

E, 21 days following inoculation and

F, 28 days following inoculation.


A
B
C
D
D
E
E
F
F
G
G
H
H
I
I
J
K

layer of wound cork had developed. He used inoculum grown in a Knop's glucose solution. In our trials, 17 days after inoculation with an aqueous suspension of spores of *S. scabies*, only sparse aerial mycelium developed on tuber slices.

Failure of *S. scabies* to produce aerial mycelium on unbroken tuber skin surfaces even though the tissues had been killed either by autoclaving or fumigating suggests that tuber skin surfaces play an important part in mature tuber resistance, even though the preponderance of evidence indicates the mechanism influencing varietal resistance to scab is probably not associated with the mature skin.

Under the experimental conditions of these trials, tuber growth was not extremely rapid nor did tubers attain large size. Despite this fact, growth patterns were apparent and scab lesion development was extensive. Tubers which were expanding at the time of scab inoculation became infected on rapidly expanding surfaces.

The circular arrangement of scab lesions around the apical end of the tuber was similar to that observed by Fellows (3). He pointed out that the apical apparently scab-free area contained infected stomata but that infection was so recent that lesions had not yet become macroscopically evident. In our trials, tubers which had been covered with ink and inoculated after evidence of further growth formed a circular pattern of scab lesions on the new skin which was a week or less in age. Apparently the scab-free apical region arose from lateral displacement of infected skin tissue and possibly also of surviving inoculum. When tubers were repeatedly sprayed with inoculum the apex became completely necrotic suggesting a lateral displacement of infected tissue when tubers were inoculated only once. Unless tubers were frequently sprayed with inoculum, the circular apical area usually remained free from scab. Under field conditions the apical ring of scab lesions is seldom encountered, due probably to more or less continuous but also to random exposure of susceptible portions of tubers to scab inoculum.

After infection, extensive and deep scab lesion development was greatest in the most rapidly expanding tubers. Even though tubers were

FIG. 3.—Representative tubers grown for observation of scab development. A, apical view of tuber 1 (see Fig. 2) 35 days after inoculation. Note the rather wide ring of necrotic tissue around the growing apical area of the tuber. B, tuber 5 (see Fig. 2) 35 days after inoculation. The apical end is somewhat raised and surrounded by necrotic spots. The deep scab area on the side of the tuber probably resulted from wound infection. C, tuber with typical ring of necrotic scabbed tissue around the apparently healthy growing portion. D, apical and longitudinal view of a tuber 10 days after being painted with India ink. Note the large apical area of rapid expansion and also that occurring around the eye. E, stolon end and longitudinal view of tuber inked 9 days before being photographed. F, apical and longitudinal view of tuber of same treatment as D inked 10 days previously. Note relatively less expansion of the apical portion and fissured type of expansion of the entire surface. G,H,I, and J, tubers which were inked when small and after growth was apparent 6 days later sprayed with a suspension of *S. scabies* spores. Photographs were made 8 days after inoculation and the margin of the India ink is indicated by small arrows. Note the area of new growth free from India ink and the location of the larger, darker scabbed areas at the margin but outside the inked areas. K, slowly expanding tuber with extensive scabbed area painted with India ink. The new tissue formed within the scabbed area was completely scabbed.

visibly infected, scab development was slow and lenticular-like lesions failed to develop further unless on vigorously growing tubers. These observations are in general agreement with those of Richardson (14). Lutman (11) pointed out that downward growth of scab tissue was due to repeated regeneration of the cork cambium. Jones (9) describes deep scab lesions as being formed by the development of successive layers of incompletely formed wound cork. Possibly, in a rapidly expanding tuber, meristematic activity may exceed that of a small but quiescent tuber and therefore tissues underlying lesions would tend to be more active and the lesions, consequently, deeper.

Wound infection of developing tubers was first demonstrated by Thaxter (18) and later by Wollenweber (19). The importance of insect wounds to scab infection was later emphasized by MacMillan and Schaal (13) and Schaal (16). Hoffman (4) was careful to maintain wound free culture in his trials. In our trials, isolated scab lesions which developed late in the observation period were undoubtedly the result of wounding by quartz sand associated either with rubbing of tubers as they expanded or during the weekly photographing and culture operations, which included adding of nutrient solution and flushing of excess salts from the sand. Lawrence (10) observed evidence of lenticel infection on detached tubers within 2 days and eruptive scab lesions after 1 weeks's incubation. Barker and Page (1) obtained common scab lesions in sterile tuber culture within 10 days after inoculation. Scab lesion development in these inverted pots required, in our trials and in those of Hoffman (4), approximately 7 to 10 days. This is a somewhat longer period of time than that described by Lawrence (10) and approximately the same time as that reported by Barker and Page (1).

Lutman et al (12) suggested that russeting in areas of normally white tuber skins may be the result of scab infection and that very superficial russeting is often localized in such a manner as to imply lenticel infection. Richardson (14) associated russeting on Katahdin tubers grown in the field with infection by scab on non-susceptible areas. The culture used in our trials consistently produced either typical punctate necrosis or deep scab and there was no evidence of russeting.

Clark (2) and Fellows (3) observed that tubers were initiated at approximately the same time and that differences in growth rate account for differences in size. Richardson (14) reported a decided tendency toward initiation of new tubers rather than toward enlargement of the small tubers which he had marked in his trials. In our trials, many tubers were formed early in the period of tuber set, however, new tubers were formed throughout the period of observation. Small newly formed tubers were more apt to enlarge rapidly than small tubers which had remained quiescent for some time. These divergent observations may well be associated with differences between varieties or between experimental conditions in the respective trials.

Clark (2), Fellows (3) and Richardson (14) report disintegration of small tubers during the growing period. In our limited observations, the majority of tubers even though very small, remained on the stolons throughout the period of observation. Only very rarely did small tubers less than 0.5 cm. in diameter or stolon tips become soft and rot.

Summary

Cut surfaces of tuber tissue of either resistant or susceptible varieties permitted abundant, macroscopically visible growth of *S. scabies* after being autoclaved or fumigated with propylene oxide. Sparse aerial mycelium developed on freshly cut, washed tuber surfaces. In contrast, macroscopically visible growth of *S. scabies* was prevented by intact skin surfaces of mature tubers which had been washed only, or autoclaved, or fumigated.

Growth of tubers was greatest at the apex. Tubers were inked and inoculated with *S. scabies* spores after tubers had begun to expand. Scab lesions developed on the newly formed (uninked) surfaces at the margin of the inked areas.

Infection of small Cobbler tubers developed at the apical end and was first evident approximately 7 days later as a ring of punctate necrotic spots around the apex. As the tuber expanded and as the necrotic areas enlarged the separate points of infection coalesced to form a ring of necrotic tissue. Infection of tuber surfaces normally developed in areas of tuber skin which were expanding rapidly.

Necrosis of stems and roots followed spray inoculations within 10 to 14 days.

Literature Cited

1. Barker, W. G., and O. T. Page. 1954. The induction of scab lesions on aseptic potato tubers cultured *in vitro*. Science 119: 286-287.
2. Clark, C. F. 1921. Development of tubers in the potato. U. S. Dept. Agr. Bull. 958.
3. Fellows, H. 1926. Relation of growth in the potato tuber to the potato-scab disease. J. Agr. Res. 32: 757-781.
4. Hoffman, G. M. 1954. Beitrage zur physiologischen Spezialisierung des Erregers des Kartoffelschorfes *Streptomyces scabies* (Thaxt.) Waksman & Henrici. Phytopathologische Zeit. 21 :221-278.
5. Hooker, W. J. 1949. Parasitic action of *Streptomyces scabies* on roots of seedlings. Phytopathology 39: 442-462.
6. Hooker, W. J. 1950. A technique for observing tuber enlargement and scab development in potatoes. Phytopathology 40: 390-391.
7. Hooker, W. J., and O. T. Page. 1951. Potato tuber growth and scab infection. Phytopathology (abstract) 41: 17-18.
8. Hooker, W. J., J. E. Sass, and G. C. Kent. 1950. Stem necrosis of potatoes caused by *Streptomyces scabies*. Phytopathology 40 :464-476.
9. Jones, A. P. 1931. The histogeny of potato scab. Ann. Appl. Biol. 18.313-333.
10. Lawrence, C. H. 1956. Infection by *Streptomyces scabies* on detached potato tubers. Canadian Jour. Microbiol. 2: 757-758.
11. Lutman, B. F. 1913. The pathological anatomy of potato scab. Phytopathology 3: 255-264.
12. Lutman, B. F., R. J. Livingston, and Alice M. Schmidt. 1936. Soil Actinomyces and potato scab. Vt. Agr. Exp. Sta. Bull. 401.
13. MacMillan, H. G. and L. A. Schaal. 1929. A pathological feature of flea-beetle injury of potato tubers. J. Agr. Res. 39: 807-815.
14. Richardson, J. K. 1952. The influence of tuber development on scab infection in Katahdin potatoes. Phytopathology 42: 297-298.
15. Sanford, G. B. 1923. The relation of soil moisture to the development of common scab of potato. Phytopathology 13: 231-236.
16. Schaal, L. A. 1934. Relation of the potato flea beetle to common scab infection of potatoes. J. Agr. Res. 49: 251-258.
17. Smith, P. G., and J. C. Walker. 1941. Certain environal and nutritional factors affecting Aphanomyces root rot of garden pea. J. Agr. Res. 63: 1-20.
18. Thaxter, R. 1891. The potato "scab". Conn. Agr. Exp. Sta. Ann. Rept. 1890: 81-95.
19. Wollenweber, H. W. 1920. Der Kartoffelschorf. Arbeiten des Forschungsinstitutes für Kartoffelbau. Paul Parey, Berlin 2: 1-102.

NEWS AND REVIEWS

SOME CONSIDERATIONS ON PROCESSING PLANT LOCATION[1]

RICHARD L. SAWYER[2]

Potato processing has made rapid advances in the past 20 years. The trend to a larger portion of the per capita consumption being in processed form continues at a remarkable rate. Conservative estimates indicate that in a relatively few years at least half of the total production in the United States will be in processed form. The plant locations of this expansion is of major importance to all potato areas and their future picture in potato production.

Areas with processing of a type which will take off-grade potatoes can grade to specification, which can eliminate competition from areas which do not have off-grade outlets. Thus, any area which does not get a slice of the processing industry will also find its fresh market industry at a serious disadvantage. For this reason every potato area is trying to attract potato processing. The recent increase in production of dehydrated potato products has given the industry some glamor which all areas would like to share.

During the early years of potato processing, there were many cases in which small one man operations ended up as multi-million dollar plants. Potato processing today does not start out like this. The plants are apt to start as million dollar or larger operations. Boards of directors, bankers, and all others concerned with sound financial investments carefully screen all prospects of each area and the plant usually goes in the area where the greatest return per dollar invested can be realized over a long period.

In the future the requirements of the processing industry will determine to great extent which areas will be able to stay in production and continue to grow large amounts of potatoes. Processors must be very discriminating in their choice of an area for plant site. Any one of several factors, from the quality of the raw produce available to the amount of the processed product on hand, can become very limiting factors for an area.

Some of the important factors to consider in screening an area for establishing a processing plant, some of the factors which processors have given for excluding an area, and some of the factors which research points out as important considerations to processors are as follows:

A. *Potato quality*—One factor which is essential to all potato processors is high total solids. This determines the yield of manufactured material which will be obtained from the raw tuber. The chipping industry has in many cases set minimum levels of acceptance for storage potatoes. Some types of potato processing can forego a certain amount of total solids for the sake of other considerations. However, when it boils down to the clear cold figures of economics of plant production, high total solids are being given major consideration in determining plant placement by large food concerns who are looking clearly at all U. S. production areas before

[1]Accepted for publication September 30, 1960.
[2]Long Island Vegetable Research Farm, Riverhead, Long Island, N. Y.

making a decision as to plant location. High total solids can be influenced by variety and by cultural and storage techniques.

B. *Climate*—The biggest determiner of total solids is the climate in which the potato is grown. Areas such as Idaho, Colorado, Maine and the Red River Valley can produce potatoes of higher total solids than can most other areas because they have environmental conditions more ideal for high total solids than many other areas. Areas with cool night temperatures and clear, sunny days with high light intensity have advantages over other areas. The warmer the producing area, particularly the night temperatures, the lower is the production of total solids. These climatic factors which influence potato production in an area can be influenced very little by man other than through irrigation. However, given the ideal climatic conditions and a suitable variety, man with the cultural techniques used in growing the crop and through the utilization of poor storage practices, can lower the value of the potatoes produced below that of potatoes from an area with less favorable climate, but with growers doing their utmost to produce a crop the processors desire.

C. *Storage facilities*—The processor, in general, has expensive custom-built machinery which requires a high overhead. It is essential for economic production, that plants be operated as near to 12 months per year as is possible. The chipping industry, because of the short shelf life of their product and the problems of transportation of their product, must produce the year around and be relatively close to their markets. This is true even though they may at times pay as much for potatoes for the two or three months supply, when local potatoes are not available, as they have paid for potatoes during all the rest of the year. The frozen French fry industry and the dehydrated industry can not afford to bring potatoes in from a distant area to keep a plant in operation. If they can't get a local source of supply year-around they must stock pile or shut down when no inexpensive local source of supply is available.

With the advent of strong sprout inhibitors and evaporative cooling for humidity control, areas with modern storage facilities and cool night temperatures which can be used to keep storages below 60° F. in the summer months can keep potatoes in good processing condition the year around. Processors of French fries and dehydrated products are therefore going to want to erect their plants in areas which can provide year around supplies. Processors of potato chips are going to want to insure, either by contract or by building their own storages in long term holding areas, an inexpensive year around source of high quality potatoes. With foresight and necessary "know how" they need no longer worry about the very high cost or low total solids potatoes for the late spring and early summer months.

D. *Cost of production* — The cost of production at the farm level is another important consideration. There are areas in the United States where potatoes can be produced at a cost of 75 to 85 cents per hundred weight into storage. Other large areas of production range from this figure on up to over $1.50 per hundredweight. A freight advantage for either raw or processed potatoes can be more than equalized by the high cost of production when there is this much variability among major

potato areas. Except for the chipping industry again, potato processing will in general tend to locate in the center of the raw source of supply. The cost of production is very important to any processor who feels he may have to eventually grow and store his source of supply.

E. *Volume of potato growing* — No processor would like to move into an area where he would have to take a major portion of the crop production for plant operation. The volume must be great enough so that the processor can be selective in his raw supplies for the whole processing season.

Many processors are unwilling to seriously consider any area where they would not ultimately be able to find land available for producing their own supply if necessary. Most processors would prefer to leave this to private growers, however, should grower bargaining get to the point whereby agreements are no longer of mutual benefit to grower and processor, the processor must be sure that he can keep his expensive plant operating even if he has to grow the potatoes himself. In some areas of the country the only way that some of the vegetable canning industry can keep its plants going at the present time is for the processor to grow most of his own produce. Potato processing, or a considerable portion of it could end up this same way. The processor seriously looking at the long term possibilities should consider this in plant placement.

F. *Spread between research-extension and grower practices* — One area of concern to processors is an important factor for both research and extension workers. It is the span between research in an area, the know how that the extension personnel have at their command, and the average practices which are used by growers. Processors are pretty sharp individuals and many of them, in screening an area, take experiment station reports with a grain of salt. They are less interested in the total solids reported by experiment station records than the total solids they can expect from average grower sources. In some areas there can be quite a margin between what the experiment station produces using the best techniques, and what the average grower produces.

The storage requirements of the processor differ from those of table stock production. Up to date storage facilities for processors in an area may be quite different from up to date storage facilities for table stock.

In one area this past winter (1958-1959), two plants only a few miles apart and with similar capacity were operating. One required only 3 girls on the peeling table to remove black spot, the other couldn't get enough girls on the peeling table to do a good job, the reason being differences in storage practices. This was in an area not normally considered to have black spot. Storage know-how is very important.

There is room for every area to get some slice of the processing business. Some areas need to quit dreaming of the glamorous aspects and visualizing a modern flake plant as solving their marketing problems. There is always a need for good chipping stock near areas of large population.

There are many questions yet to be answered by research and extension personnel. One producer has built up an association with a chipper

over a period of years, using a variety well known for producing problems. This grower, in an area not normally looked on as producing good chipping potatoes, has learned to handle this variety to the chippers' satisfaction. The chipper has found this grower's potato quality more dependable than that of normal buying channels. Thus, from a small potato state, approximately 1000 acres of potatoes are sold annually to the mutual satisfaction of both parties using a poor chipping variety.

Research workers in every area should look clearly at the processing picture and determined what it can do for and to their areas in the future. Some of the unanswered questions may seriously determine the future of processing in the area. For example cold storage areas, which have in the past only had to worry about keeping potatoes from getting too cold, may now find that they have problems similar to the warmer storage areas, for at least a portion of the year, as they go into year-around holding.

Don't forget the factors of drainage, waste disposal, low total solids, etc. until after you start processing in an area. News of a closed plant spreads like wildfire. Face the problems and get them solved first and don't take a chance on the very poor publicity a closed plant could bring to an area.

The following key questions will give a pretty good picture of the processing potentials which might be expected, the limiting factors at the present time, the factors which research and extension might do something about.

1. Do you know how to grow varieties in the area which the processor will accept?
2. Can the growers meet processors' requiremtnts?
3. What is the climate?
4. What are your storage facilities, how modern, how adaptable to processing requirements? Can you utilize sprout inhibitors which will help keep potatoes year around?
5. How consolidated is the industry — how much processing is there now?
6. How strong are grower organizations and what is their attitude towards processing?
7. How does your cost of production compare with other areas?
8. Are grower practices keeping pace with extension and research results?
9. How many of the unanswered problems are being worked on at present?

USDA POTATO ADVISORY COMMITTEE URGES CONTINUED EMPHASIS ON BASIC RESEARCH

Continued emphasis on basic studies in all areas of agricultural research was urged by members of the U. S. Department of Agriculture's Potato Research and Marketing Advisory Committee at their annual meeting in Washington, Nov. 28-Dec. 2.

The highest priority in assigning USDA research funds should be put on fundamental studies, according to the committee, which also noted recent Congressional appropriations to strengthen basic research on use of farm chemicals.

The committee also called for marketing studies that will enable the potato industry to deliver to consumers improved fresh and processed potato products while retaining a reasonable profit for growers, processors, and potato marketers. Especially needed is work to improve crop reports and estimates, the committee said. The following kinds of information are needed: (1) estimates of acreage and production of reds, round whites, long whites, and russets; (2) utilization by seasonal groups, (3) semimonthly disappearance of the fall crop, (4) short supplies and movements of other seasonal groups, (5) January planting intensions, (6) monthly production and stocks of processed potato items, and (7) a weekly report and three-year statistical averages, rather than the present 10-year tables.

Marketing research needs cited by the committee include expanded basic research on the post-harvest physiology of potatoes and on effects of preharvest, harvest, and post-harvest conditions on disease decay during storage.

New basic research on factors in the environment that affect potato quality is the most important need in the area of farm studies, the committee said. These factors include temperature and moisture of the air and soil, light and other weather elements; nutrients, growth regulators, weed killers, top killers, and pesticides.

New work on insect vectors of potato diseases and control of diseases with antibiotics are also important farm research needs, according to the committee.

Fundamental studies of the chemical composition and physical properties of potatoes, to aid in developing new and improved potato products, is the most important utilization research need, the committee said. Also important is new research to develop additional products for both domestic and foreign markets.

Established under the Research and Marketing Act of 1946, the committee is made up of national leaders from the potato industry. Its detailed recommendations for potato research to be undertaken by USDA will be submitted formally to the Department within the next few weeks. Copies of this report will be available from the committee executive secretary Dr. Roy Magruder, Office of the Administrator, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

Loren Voth, committee chairman and partner in H. H. Voth and Sons, Wasco, Calif., growers and shippers, presided.

Other committee members are :Dr. N. Kent Ellis of the Indiana

Agricultural Experiment Station, Lafayette; Bruce Gray, member of the board of Florida Planters, Inc., cooperative, Hastings, Fla.; G. W. McGrath, president of the Seaboard Supply Co., Inc., grower and shipper, Onley, Va.; Ivan Miller, grower and director of Pennsylvania Cooperative Potato Growers, Inc., Corry Pa.; Ben Picha, grower and shipper, Grand Forks, N. D., Edward J. Rollins, president of Taterstate Frozen Foods, Washburn, Maine; John D. Snow, National Produce Distributors, Inc., Burley, Idaho; Ted Still, committee vice-chairman and grower and shipper, Monte Vista, Colo.; and Harold W. Wilkens, vice-president in charge of produce operations, National Tea Company, Chicago.

FOOD FOR AMERICA'S FUTURE

Twelve distinguished authorities in related fields of agriculture affirm their belief in America's ability to feed her multiplying millions in years to come in a concise and readable volume, "Food for America's Future"—the result of a study undertaken by the Ethyl Corporation and published by McGraw-Hill on October 17, 1960.

Concluding that the nations farms and industries can keep pace with a population which is estimated to increase by 65 million within the next fifteen years—bringing the number of Americans to 245 millions by 1975—the authors explore what has been, is being, and will be done to better equip our farms and industries to provide ample food for this rapidly growing population.

Increased agricultural research and more efficient management of land, labor and capitol, the authors assure us, will play a large role in helping boost our farm output. Continuing strides in chemical and other technological developments for control of insects, disease, and weeds, and for more productive fertilization of farmlands will lead to greater productivity. More and better food for more people will be provided through the encouraging advances taking place in food processing, packaging and marketing. Of great importance, too, will be the wider use of power farming to increase productivity and the availability of petroleum products for powering equipment. Electricity, of course, will continue to play a major role in the business of farming.

Finally, the authors point out, a large part of the responsibility for meeting the farmer's needs and problems of tomorrow will rest with the agricultural colleges which must be prepared to change their curricula to embrace the ever-widening horizons of research and experimentation in agriculture.

Among the authorities contributing to "Food for America's Future" are Firman E. Bear, Editor-in-Chief, *Soil Science;* Byron T. Shaw, Administrator, Agricultural Research Service, U. S. Department of Agriculture; Thomas A. Boyd, Consultant, General Motors Research Staff; Clifford M. Hardin, Chancellor, University of Nebraska; Herrel F. DeGraff, Babcock Professor of Food Economics, Cornell University; Richard C. McCurdy, President, Shell Chemical Company; Kenneth S. Adams, Chairman of the Board, Phillips Petroleum Company; Robert S.

Stevenson, President, Allis-Chalmers Manufacturing Company; Robert E. Wilson, Chairman of the Board (retired), Standard Oil Company of Indiana; Philip D. Reed, Chairman of the Board (retired) General Electric Company; Charles G. Mortimer, Chairman and Chief Executive, General Foods Corporation; and Charles B. Shuman, President, American Farm Bureau Federation. B. B. Turner, President of the Ethyl Corporation provides an enlightening forward to "Food for America's Future".

WALL CHART OF CONVERSION FACTORS

A valuable wall chart containing scores of conversion tables used by research workers, engineers and laboratory technicians is available free of charge to readers of the American Potato Journal. It gives conversion factors for changing such measurements as: Cubic centimeters to cubic feet, cubic feet/min. to Cubic centimeter/sec., degrees all cubic measurements, weight measurements, temperature measurements, horse power, etc.

For your free wall chart of *Conversion Factors* write on your business letterhead to Precision Equipment Co., 4411 Ravenswood Ave., Chicago 40, Ill.

American
POTATO JOURNAL

Official Organ of the Potato Association of America

VOLUME 37

JANUARY - DECEMBER 1960

INDEX TO VOLUME 37

AUTHOR AND TITLE INDEX

ERRATA, Volume 37

Front Cover, Vol. 37, No. 6, date line: *read* June 1960 *for* Juue 1960.

Front Cover, Vol. 37, No. 6 contents: *read* Henning P. Hansen *for* Henning P. Hanson.

Page, 187, by-line: *read* Henning P. Hansen *for* Henning P. Hanson.

Pages 233 and 234, Figs. 1 and 2: The description of each figure is correct; the graphs *only* are reversed.

Numbers in parenthesis indicate page numbers of junior author's articles.

SUBJECT INDEX

American potato jnl.

1960

POTATO HANDBOOK

Potato Processing Issue

PUBLISHED BY

THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, NEW JERSEY

Volume V

1960

POTATO HANDBOOK

PUBLISHED BY

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, N. J.

Single Copies — $2.00

EXECUTIVE COMMITTEE

SPONSORS

Campbell Soup Company	Camden 1, New Jersey
General Foods Corporation,	250 North St., White Plains, New York
Jays Foods, Inc.	825 E. 99th St., Chicago 28, Illinois
McCain Foods Limited	East Florenceville, New Brunswick, Canada
Old Dutch Foods	520 Flour Exchange Bldg., Minneapolis, Minnesota
Red Dot Foods, Inc.	1435 E. Washington Ave., Madison, Wisconsin
Seabrook Farms Company	Seabrook, New Jersey
Snowflake Canning Company	Hartland, Maine
Taterstate Frozen Foods	Washburn, Maine
Utz Potato Chip Company, Inc.	Carlisle St. & Clearview Rd., Hanover, Pa.
Wise Potato Chip Company	228 Raseley St., Berwick, Pennsylvania

Editor and Advertising Manager

JOHN C. CAMPBELL

Rutgers University New Brunswick, N. J.

Table of Contents

JOIN THE POTATO ASSOCIATION OF AMERICA

To you who are not members of The Potato Association of America we give you this invitation to join.

The Potato Association of America was founded in 1913 to unite research workers, growers and others interested in the white potato industry in an effort to improve the industry through the publication of research findings and other pertinent facts.

We have published a Journal monthly since 1923 and today the American Potato Journal is recognized throughout the world as the foremost publication devoted to the publication of the latest results of research in all phases of the industry.

Any person or firm interested in the potato industry may become a member of The Potato Association of America. All members will receive the American Potato Journal monthly and the Potato Handbook annually. Dues are $4.00 per year in the United States, Canada and Mexico and $5.00 in other countries.

Fill in the blank below and mail it with your dues.

The Potato Association of America,
Nichol Avenue,
New Brunswick, New Jersey.

Enclosed are $4.00 ($5.00 in foreign countries) for a year's membership in The Potato Association of America. This includes a subscription to the American Potato Journal and the Potato Handbook.

Name ....

Address ....

....

THE UTILIZATION OF OUR POTATO CROPS

A. E. MERCKER[1]

The 1958 potato crop, which was the second largest crop of record, presented a distinct challenge to the potato industry, for a crop of this magnitude resulted in very low prices to the producer, which, for the 10-month period of July 1958 through April 1959, averaged about 50 per cent of the parity price for potatoes. The production in the late Summer and Fall States of 207 million cwt., was over 40 million cwt. more than the Department of Agriculture had determined to be necessary to meet all of our needs.

The problem of utilizing such a large crop was a difficult one. The Department of Agriculture was extremely helpful in furnishing a program to divert the surplus potatoes to non-food uses. The marketing agreement areas met the challenge and diverted about 1¾ million bushels a week into starch and livestock feed. About 55 million bushels were diverted in the marketing agreement areas by May 2. The diversion involved many problems, such as the sale and disposition of the starch manufactured and the judicious use of the potatoes for livestock feed. Probably 13 per cent of the crop was fed and 7 per cent was diverted into starch. An additional 7 per cent was used as seed to plant the 1959 crop.

Exports received an indirect beneficial effect from the short European and South American crop so that our exports increased by 20 per cent, due almost entirely to the large increase in potato shipments to Venezuela which was the second largest importer of United States potatoes. Because of the shorter crop in Canada and the very low prices, imports into the United States were 60 per cent lower than those of the previous year. The net result was that almost 30 per cent of the crop was used for non-food purposes.

[1]Executive Director, National Potato Council, Washington, D. C.

PROCESSING INCREASING

The preliminary indications are that per capita consumption was around 108 pounds, or 3 pounds more than that of the 1957 crop. The increase, however, is due largely to the 20 per cent additional quantity of potatoes that was used by the food processing industry which utilized 18 per cent of 1958's total production or almost 28 per cent of the quantity of potatoes used for food.

There seems to be no let-up in the increase of potatoes for processing into potato chips and the industry seems to increase at a rate of about 10 per cent a year. The potato chip industry is concerned with consolidations and we are finding that many companies are being absorbed by larger corporations or consolidated into corporations. It has been, generally, a profitable industry.

The frozen French fried potato industry has had a rapid development but received a setback in 1957 when 225 million pounds of frozen prepared potato products were produced. From the 1959 crop it is my estimate that 350 milion pounds will be produced and that by 1960 probably 400 million or more pounds may be produced.

The demand for the quickly reconstituted mashed potato is also increasing rapidly. From 20 million pounds used from the 1956 crop and 40 million pounds from the 1957 crop, I estimate that this product will use 80 million pounds or more from the 1958 crop and possibly as much as 200 million pounds from the 1960 crop.

Dehydration for cubes has increased appreciably whereas canning

U. S. Production, Utilization and Use of Designated Potato Crop[1]

CROP YEAR	1940	1950	1955	1956	1957	1958[2]
			1,000 BUSHELS			
Production	375,920	431,940	378,486	406,193	399,232	439,367
Imports	930	5,349	3,648	3,227	4,771	2,633
TOTAL SUPPLY	377,850	437,289	382,134	409,420	404,003	442,000
Exports	2,495	5,534	6,590	5,130	4,217	5,000
Shipments to Territories	1,788	1,109	1,309	1,092	622	1,000
TOTAL OFF SHORE SALES	4,283	6,643	7,899	6,222	4,839	6,000
Available Domestic Use	373,567	430,646	374,235	403,198	399,164	436,000
Used for Seed	41,985	29,079	32,465	33,343	35,030	32,500
Fed to Livestock[6]	37,238	100,869	28,395	37,700	42,735	58,000
Starch[6]	8,030	21,682	20,752	28,785	20,440	30,000
TOTAL NON FOOD USE	87,253	151,630	82,612	99,828	98,205	120,500
TOTAL FOOD USE	286,314	279,016	291,623	303,370	300,959	315,500
Military Use—Fresh	......	8,000	7,000	7,000	7,000	7,000
Est. Civilian Use	286,314	271,016	284,623	296,360	293,959	308,500
PROCESSED[3]						
Flour[6]	400	1,200	2,900	3,000	2,000	3,000
Dehydration[6]	......	3,081	4,700	5,000	6,800	11,700
Canning	......	865	1,300	1,400	1,600	2,000
Hash, Stews, Soups	500	1,500	800	1,300	2,370	2,500
Frozen French Fried	......	1,200	7,700	9,000	8,000	12,000
Potato Chips	4,500	21,200	39,346	45,000	45,000	47,000
TOTAL PROCESSED	5,400	29,046	56,746	64,700	65,770	78,200
Est. Sold to Restaurants[3]	40,000	57,500	65,000	65,000[4]	65,000	65,000
Total Use for Processed & Restaurants	45,400	86,546	121,746	129,700	130,770	143,200
Est. Total Used Fresh in Homes	240,914	184,470	163,377	165,670	163,189	165,300
Used on Farms	63,099	29,073	20,703	18,272	17,660	18,000
Purchased Fresh for Home Use[5]	177,815	155,397	142,674	147,398[5]	145,529	147,300[5]
Civilian Population July 1 (Millions)	134.0	152.3	164.5	167.5	168.4	171.4
Per Capita Consumption Crop Year – Civilian	128.0	106.8	104.0	106.2	104.7	108.0
Per Capita Consumption Calendar Year – Pounds	121.0	102.0	103.0	100.0	105.0	102.0
Per Capita Pounds Processed Used as Food – Pounds	1.9	11.4	20.7	23.5	23.4	27.4
			% Prod.		16.5	17.8

[1]Source: Agricultural Marketing Service except as noted.
[2]From December 1958 USDA Crop Report. All other figures in columns are estimates of the National Potato Council Exports-Imports May through April.
[3]Industry Estimates.
[4]Includes an estimated 6,000,000 bushels of prepeeled potatoes.
[5]Includes an estimated 85,000,000 bushels packed in consumer-size packages of 25 lbs. or smaller.
[6]Includes quantities processed to starch and flour or fed under the USDA diversion programs.
Revised Jan. 1959

of potatoes is increasing at a slower rate. The quickly reconstituted dehydrated potato products, the frozen prepared potato products and canned potatoes supplied about three and three-quarter billion meals, or two per cent of all the meals served. The potentiality is so great that within five to eight years these types of potatoes may be used in 10 per cent of all meals. The cost to the restaurant of the frozen prepared potato product is

around 5-cents per serving and for the quickly reconstituted mashed potato from 1¼ to 1¾-cents per serving. The question I raise is, when stocks of the prepared ready-to-eat potato products are large, will they put a ceiling of $3.50 to $4.00 per cwt. on potatoes delivered to the restaurant? In years of shortages, or even temporary shortages, producers received good prices. Will these stocks of convenience potatoes modify or eliminate these advantageous price periods? There is no standing in the way of progress and as long as people have ample money they will increase the use of convenience products.

By unity of action of all the different segments of the potato industry, from the grower, processor, distributor and retailer, the potato industry has shown the way to other commodities how to dispose of a surplus at a minimum cost to the government. The industry should be congratulated for its leadership in agriculture on initiating its own self-help programs.

The preceeding table presents production and utilization estimates of designated potato crops.

BACK ISSUES

Back issues of he American Potato Journal, an Index to the first 26 volumes ($3.00) and 4 previous issues of the Potato Handbook devoted to Seed Certification, Disease Control, Potato Machinery, and a description of American Potato Varieties are available. The Handbooks are now reduced to $1.00 each with substantially lower prices for quantity orders. Additional copies of this Handbook are also available at the following prices: 1 to 10 at $2.00; 10 to 25 at $1.50; 26 to 50 at $1.00; 51 to 100 at 50¢ and over 100 at 25¢ each.

POTATO CHIP PROCESSING[1]

ORA SMITH[2]

The growth of the potato chip industry in the United States has been phenomenal. From about 2.5 million bushels in 1940 the industry has expanded rapidly until 1958 when about 45 million bushels were processed into chips. Prospects appear bright for continued growth of the industry and increased demand for high quality potatoes suited to this industry. Potato chips are made in every state in the country and are distributed and consumed in practically every settlement regardless of size. They are a good steady outlet for potatoes and comprise about one-sixth to one-seventh of all potatoes consumed as food. In recent years potatoes for potato chips have been increasing 3 to 3.5 million bushels annually.

GROWING POTATOES FOR CHIPS

One of the most important duties of a potato chip processor is the selection of his raw materials and of the raw materials which he uses the potato is the most important. Quality of the raw stock varies considerably among varieties and within the variety when grown under different soil and environmental conditions. It also is tremendously affected by temperature during storage and transit. In many instances, the potatoes which a processor receives are absolutely worthless to him for processing no matter how good they look on the exterior. A processor must be supplied with potatoes that will process into desirable light colored chips and be of relatively low oil content. The yield of chips from the potatoes should be high.

Growing and handling potatoes by routine methods for supplying the fresh market trade may not be the best for the chipping industry. Practically everything a grower does in producing a crop of potatoes has some effect on the quality of chips or yield of chips made from them.

The number one requirement of a potato is that it process into a light color chip. People "eat with their eyes" and since the consumers' choice is predominantly for an attractive golden color chip, the processor finds his sales decreasing when he is unable to produce that quality.

Some of the basic factors on which a chipper should make his choice of potatoes are: (1) grade, (2) variety, (3) specific gravity, (4) maturity and (5) the storage conditions preceding purchase. Various cultural factors such as irrigation, fertilizer program, spray program for the control of insects and diseases, methods of vine killing and others will also determine whether or not the potatoes are desirable for chipping. All of these will be discussed in this article.

(1) **Grade.** The choice of the particular grade of potato varies considerably from processor to processor. It is not the most important thing to be considered in his choice since it concerns largely the exterior appearance of the potato. Most processors are not as critical of the outward appearance of the potato as is the housewife. He is, however, interested in the size of tubers, amount of defects, rots, second growth, growth cracks, green tubers, and hollow heart. The amount of defects and also the size of tubers determine the loss in peeling and hand trimming. This is important.

---

[1]A summary of a chapter by the same author in the recently published book *Potato Processing*, edited by W. F. Talburt and Ora Smith, and published by the Avi Publishing Company, Westport, Connecticut.

[2]Professor, Department of Vegetable Crops, Cornell University and Director of Research, Potato Chip Institute International, Ithaca, N. Y.

Some chippers consistently buy nothing but U.S. 1 grade, others buy commercial grade and some think that field run potatoes are the best buy. Some may purchase one grade part of the time and another grade for another part of the year depending on price, quality and performance and what appears to be the best bargain. But keep in mind – no matter how good they look on the outside they must make crisp, tasty chips of light golden color. If they don't meet this standard they are worth little or nothing to the processor – unless he can't get anything better.

(2) **Variety. What is desired in a variety?** Above all, it must process into a chip of light color, not only a portion of the year but during the entire storage season. Every slice and all portions of each slice preferably should be of uniform light golden color. Many potatoes will produce chips which are light at the apical end and dark at the basal end. These are undesirable and must be picked out and thrown away or if left in they lower the quality of the product. A potato may boil, bake or mash to a beautiful snow white and yet be worthless to the chipper because it fries too dark. The chemicals in the potato which result in these discolorations are entirely different in their reaction and, therefore, different treatments are necessary to prevent them.

A variety also should be of high specific gravity so that it will result in a high yield of chips of relatively low oil content. This is very important to the processor and to a great degree it determines the extent of his profits. The higher the specific gravity of potatoes the lower the oil content of the chips. Oily chips are not highly desirable and are costly to produce because of the cost of oil. The chips also should be crisp, of good flavor, without blistering and with no effects as a result of hollow heart, vascular discoloration or stem end browning.

There is no one variety which meets all of these requirements at all times. Growing conditions and production areas influence these factors so that a variety may perform well at one time of the year but not at another or from one growing area but not from another. So choosing by variety alone is not sufficient. There can be as much difference between the same variety grown under different conditions or in different areas as there is between any two good varieties.

Considering all of these factors the following varieties are recommended for chips when they are grown in the areas to which they are well adapted: Russet Rural, Smooth Rural, Russet Burbank, Irish Cobbler, Kennebec, Sebago, Katahdin and Cherokee. The Chippewa produces chips of acceptable color but usually the specific gravity is so low that the yield of chips is low and oil content is high. Of the potatoes that are not stored but are processed in the spring and early summer the White Rose from California and Sebago from the southern states are acceptable. Some of the outstanding newer varieties worthy of trial are Delus, Saco, Merrimack and Plymouth.

(3) **Specific gravity of potatoes.** This is an excellent tool or yardstick to determine the processing quality of the potatoes which the grower has for sale. As mentioned earlier it determines the yield and oil content of the chips and to some degree it also affects chip color. It should be high, indicating that the potatoes are low in water content. Every grower or dealer who is interested in selling to the potato chip trade should have a "potato hydrometer," an instrument which quickly and accurately determines the specific gravity of any lot of potatoes. These instruments are manufactured and sold by the Potato Chip Institute International, 946 Hanna Building, Cleveland 15, Ohio.

The factors which affect specific gravity of potatoes during the grow-

ing season will be discussed later in this article.

(4) **Maturity of potatoes.** Maturity is highly desirable in potatoes for chipping. Immature potatoes usually are of low specific gravity and hence result in low yields of chips with a high oil content. The color of chips from immature potatoes which are stored is likely to be undesirably darker than that of chips from mature potatoes. Mature potatoes also are more quickly and satisfactorily reconditioned for chip making after storage than are less mature tubers. The chemical composition of mature and immature potatoes is considerably different and in favor of the mature tubers. Immature potatoes such as those harvested in southern California and in the southern states process to a desirable color if they are fried soon after harvest and are not subjected to cool temperatures during transit.

Maturity can be obtained best by planting as early as possible, harvesting late and by killing potato vines fairly slowly so that food manufactured in the leaves can be translocated to the tubers. A fairly low nitrogen and potash supply, a high phosphorus supply and not too much rainfall or irrigation also will hasten maturity.

FACTORS AFFECTING MATURITY, AND SPECIFIC GRAVITY OF POTATOES AND COLOR OF POTATO CHIPS

Specific gravity of potatoes and color of potato chips depend on the chemical composition of the tubers. The chemical composition is influenced by a number of factors which are discussed here.

(1) **Variety.** This topic has been discussed earlier in this paper. Some varieties, such as Green Mountain, are never used for potato chips because their chemical composition is such that chips made from them always are too dark. Because of this they are not processed although their specific gravity is consistently high. A good choice of a variety would be from one or more of those mentioned earlier.

(2) **Soil type.** Type of soil in which potatoes are grown may affect specific gravity of tubers because of its moisture content and consequent temperature. For instance, a sandy soil would be of lower moisture content than a loam or clay loam soil. In a wet season this could be an advantage and result in potatoes of higher specific gravity. In a dry season, however, it may result in lower yields but the potatoes might still be high in specific gravity unless the season is very hot. A soil high in moisture content will usually be several degrees cooler than a similar soil of low moisture content. This cooler soil may result in higher specific gravity tubers because less food is lost from the potatoes by respiration.

As a general rule, potatoes grown in muck soil are of lower specific gravity than are those grown in mineral soil in the same area.

(3) **Date of planting** is very important in determining specific gravity and maturity of potatoes. Early planting lengthens the season of growth and results in greater maturity at harvest time than from any later planting.

(4) **Date of comeup of plants** is very important since that determines the time at which the plants start to manufacture their own food. This also affects maturity and specific gravity of the tubers. If the soil is dry or cold after planting, the time of comeup will be delayed and the growing season therefore, shortened. Hence, date of comeup actually is more important than date of planting for determining specific gravity and maturity of tubers.

(5) **Kind and amount of fertilizer applied** also affects maturity and specific gravity of the tubers. Greatest yield response in potatoes in most potato growing areas results from ap-

plications of nitrogen, either in the complete fertilizer or as a sidedressing in addition to the complete fertilizer. Nitrogen promotes extensive vine growth and prolongs the growing period. As a result, potatoes do not become mature by harvest time and, therefore, chemically, are poor risks as chipping potatoes after several months of storage at 40° F. Use sufficient nitrogen to obtain good yields, but not an excess which results in vine growth until they are killed by frost or by the grower. Immature potatoes are more difficult to store and lose more weight in storage than do mature ones. More important, however, they are much more difficult to recondition after storage in order to obtain light colored chips. So – go easy on the nitrogen.

Potash also affects the specific gravity of potatoes. When heavy applications of muriate of potash (KCl) are made, either alone or more commonly in a complete fertilizer, specific gravity generally is decreased. This decrease is a result largely of the chlorine rather than the potassium portion of the fertilizer. Therefore, the use of some other form of potash may increase specific gravity – and it does. Sulfate of potash, when applied to the soil to supply the same amount of potassium as in muriate of potash, usually results in higher gravity potatoes. Where magnesium deficiency exists, it may be desirable to supply part of the potash as sulfate of potash-magnesia and the remainder as sulfate of potash. So – for higher gravity potatoes, try the sulfate form of potash rather than the standard muriate.

(6) **Rainfall, irrigation and soil moisture** affect the quality of potatoes for processing. Up to a certain point, of course, these factors are necessary for growth of the potato plant. Usually, however, maturity is promoted and specific gravity is higher when potatoes have been grown in low to medium soil moisture than at high soil moisture. Therefore, it is best not to irrigate too heavily or too late in the season unless temperatures are very high. As mentioned earlier, a dry soil will reach a higher temperature than the same soil when moist and in hot seasons this may result in lower specific gravity tubers because of greater loss of food by respiration.

(7) **Spraying for control of diseases and insects** also has an effect on the quality of potatoes for chipping. In most areas it is necessary for the grower to spray or dust with Bordeaux mixture, insoluble coppers or organic fungicides such as nabam for the control of fungus diseases, especially early blight and late blight. There is no evidence that this procedure is harmful to potato chipping quality except that it delays maturity of the plants. It is a necessary evil as far as potato processing quality is concerned.

For insect control DDT is most extensively used. Because of its successful control of most common foliage insects it prolongs growth, delays maturity and, in most instances, necessitates vine killing. It is recommended that DDT be omitted from the fungicide spray during the last 2 or 3 applications. This may result in more mature potatoes than if DDT applications were made later in the season.

(8) **Killing potato vines.** Before the days of DDT it was not necessary to kill potato vines for table stock potatoes; insect injury did it for us. While the insects were slowly killing the plants there was translocation of manufactured food from the tops of the plants to the tubers. This food (sugar) was converted to starch resulting in high specific gravity potatoes. When our modern rapid methods of vine killing are employed, there is little or no opportunity for transfer of food from the tops to the tubers. Lower specific gravity and different chemical composition of the tubers result. It is best therefore, to kill

potato vines slowly if possible, or to kill them as late as possible. All of our experiments show that specific gravity of tubers was higher from plants killed slowly (such as by chemical sprays) than by rotobeater if both were done on the same date.

(9) **Date of harvest.** In order to get as mature a potato as possible, harvest should be delayed as long as possible without subjecting the potatoes to too low a temperature. Potatoes should not be chilled or allowed to frost in the field before or during digging or in transit to the storage. Undoubtedly some potatoes are ruined for use as chipping potatoes by exposure to temperatures under 40° F. before they reach the storage. It is very important to have a record of the day and night temperatures which prevailed in the field during the last 2 weeks of growth before harvest and during harvesting operations.

ADDITIONAL FACTORS OF IMPORTANCE

The grower should know all he can about the following subjects and be able to give the information to the processor so that he can follow it up in the processing plant with performance of the potatoes as chips.

(1) **Were sprout inhibitors applied in the field?** It is necessary to store potatoes at about 40° F., to prevent sprouting. However, storage at this low temperature results in accumulation of sugars and other chemical changes in the tubers which result in dark colored chips. This necessitates long, costly periods of reconditioning at high temperatures to obtain desirable color. In some seasons and with some varieties and with immature potatoes this sometimes cannot be accomplished at all or within a feasible length of time. It would be desirable to have potatoes treated so that they could be held at 45° to 50° F. or higher for some time without sprouting or with few short sprouts.

Spray applications with maleic hydrazide (MH-30) to plants in the field late in the season has greatly reduced sprout growth of potatoes when stored subsequently at 50° F. This should be applied about the time that a few lower leaves start to turn yellow and die or 4 to 6 weeks before harvest. A rate of 1 gallon MH-30 per acre is recommended. This material costs about $15.00 per acre. This application should not be made to potatoes which are to be used for seed since it may keep them from growing even after they are planted. Several other chemicals for preventing sprout growth are available but they are not yet recommended for use because of lack of clearance with Food and Drug Administration or because of excessive cost or for other reasons.

(2) **Prevalence of late blight or other diseases affecting tubers.** Growers should record the dates of spray or dust applications of fungicides and the material which was used. If any blight, etc., is present it should be noted and potatoes from these areas should be stored separately and not be offered for sale to processors.

(3) **Potatoes should be handled carefully.** A great amount of damage to potatoes often results during harvesting. An excellent crop can be ruined by bruising, skinning and cutting tubers during digging, picking up, transporting and unloading into storage. Roughly handled tubers result in poorer keeping quality and extra work and loss at the trimming table.

(4) **Conditions during transit.** Potatoes should be held between 45° and 75° F. during transit. If held at too low a temperature or if iced too much in transit they may result in chips that are too dark. Temperatures above 75° for very long periods of time, especially in fairly tight ve-

hicles may result in blackheart. Ventilation in cars or trucks during shipment is considered highly desirable..

(5) **Conditions during storage.** Farm storages or other storage structures adapted to the storage of potatoes for the fresh market are usually not the best for chipping potatoes. Control of temperature and ventilation or air movement is much more important for potatoes to be made into chips. Automatic controls are highly desirable.

The building should be well insulated. There should be exhaust fans in the roof or in the peak of a gable end for good exchange of air.

In general, bins should be smaller than for table stock potatoes, not more than 10 feet wide and the potatoes 10 to 14 feet deep. In order to keep potatoes from being in an area of poor air circulation, it is suggested that the lower part of the bin side walls be tapered toward the center of the bin floor. With air ducts 24" wide and 16" deep in the floor of the center of the bin running from front to back, air movement from the duct up through the pile is assured. Thus the pile is warmed up or cooled off as rapidly as desired and excess moisture is removed. With constantly recirculated air there are no dead air spots nor any temperature stratification in the bins. Air is taken from the ceiling of the room and forced through the duct system below the bin floors. Warm air when needed is best brought in at 70°-80° F. from a heated room adjoining the storage. This is often done by the use of a thermostat controlling a damper motor. The use of a cooling action thermostat and time clock which operates an exhaust air system which brings in outside air when lower temperatures or an air change is desired, is helpful. Storage in pallet boxes or crates of 1,000 to 2,000 pounds capacity is becoming increasingly popular in the chip industry (Figure 1).

PERFORMANCE OF THE POTATOES IN THE PROCESSING PLANT

The pay off on all the above mentioned information is, of course, the quality of the chips which are made from these potatoes.

The grower, after following the best known methods for producing and handling potatoes for processing should have a good record of how the crop was produced and stored. This information should then be given to the processor so that he can relate this to the quality of chips produced from the potatoes. If color of chips, for instance, is good in one shipment and unsatisfactory in another, the chances for finding what caused this difference is much greater if the processor has all the information on these two lots as listed above. If he does not have this information and cannot get it from the grower, he may not be able to use this second lot. If he had the necessary records it might be possible to alter storage temperature or some other factor so that the potatoes would be of use to him..

After several seasons of such records as called for above, the processor and the grower will have a better idea which procedures to continue and which to avoid in order to be assured of satisfactory potatoes for chipping.

TECHNOLOGY OF POTATO CHIP PROCESSING

When potatoes are ready for processing, either directly from the field or from the storage or reconditioning room, they are dumped into hoppers where stones and any trash are removed. They then move on belts or chains into a washer and thence into the peeler.

Peeling – Abrasive peelers are used almost exclusively in the chip industry. Both batch and continuous peelers are widely used. Peeling time is variable depending upon the matur-

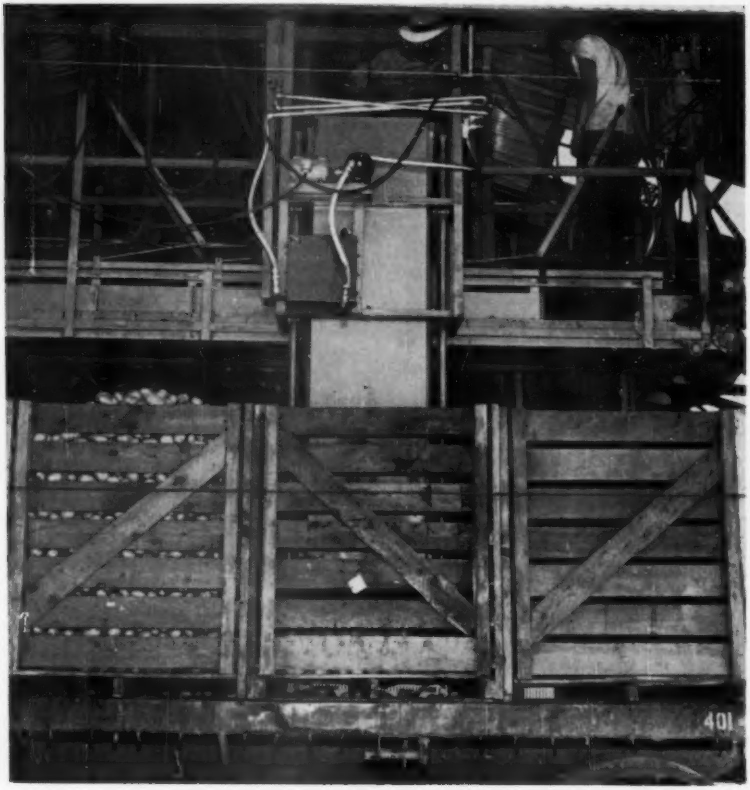


FIGURE 1.—Loading 1 ton capacity palletized crates with automatic loader to reduce injury. *Photo courtesy Granny Goose Foods.*

ity, thickness of skin, time of year, amount of defects, shape of tuber and other factors. Peeling loss also is influenced by the above factors and varies from 1 to 4 per cent of the original weight of the potatoes. Peeled potatoes are washed thoroughly and inspected for the removal of low grade potatoes or portions. Trimming losses may range from almost nothing to as high as 10 per cent. It is important that rigid trimming be done rather than wait until after slicing and frying before removal of the defective areas.

Slicing and washing – Several types of rotary slicers are now in common use, some with a capacity of two tons of potatoes per hour. Thickness of slice varies with the age, turgidity, variety and sugar content of potatoes as well as the cooking time and temperature of the oil. Thickness of slice varies from 1/15 to 1/30 inch but it is very important that the slices are of uniform thickness at any time and that the cut surfaces be smoothly cut rather than mashed or torn. Slices are washed in rotating reels to remove surface starch and to screen out the slivers and odd-shaped pieces.

Slices are removed from the washing tank on a conveyor belt and dropped into a rinse tank. After rinsing they are moved by conveyor belt to the frying kettle. In some plants the surface water on the slices is removed by sponge rubber covered squeeze rollers, compressed air and blower fans, vibrating mesh belts, heated air, centrifuging or other means. Also some plants are equipped to treat potato slices which would otherwise result in chips too dark to be acceptable. The slices are passed through a tank containing hot water or a hot solution of some chemical or combination of chemicals such as citric acid, sodium bisulfite, phosphoric acid or similar materials. These usually immediately precede the frying kettle.

Chip frying machinery – Chips may be fried by the batch method or the continuous method. Only very small establishments employ the batch method of cooking in this country. The larger continuous machines process from 4,000 to 8,000 pounds of raw potatoes per hour. Rinsed slices are dropped into the oil in a rectangular flat bottom kettle at one end and slowly moved toward the opposite end where they are removed on a stainless steel chain belt. The slices, as they are moved forward, also are dipped or pressed under the surface of the oil by a series of baskets or rakes. Usually the oil is heated with natural gas or fuel oil-fired burners under the receiving end of the frying kettle. The newer type kettles use the principle of indirect heating of the oil utilizing a heat exchange medium such as Dowtherm or other similar material. The exchange medium is heated and pumped through pipes that are placed in the cooking oil releasing its heat to the oil. In this method the oil is not likely to be overheated at any time and thus results in less breakdown of the cooking oil.

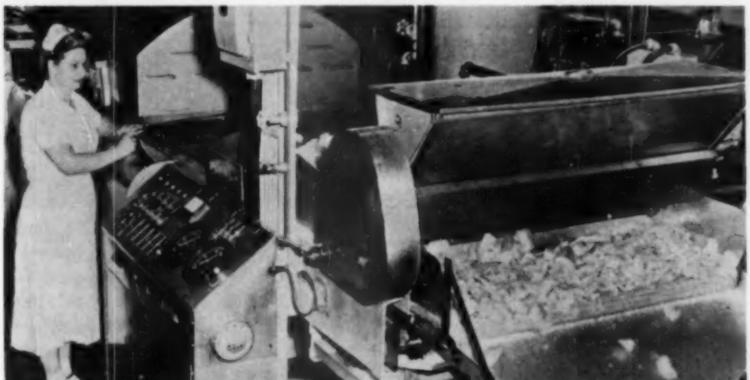


FIGURE 2.–A modern chip frying unit. This machine, which is controlled by one operator, will produce 750 pounds of potato chips per hour. *Photo courtesy Red Dot Foods, Inc.*

As the chips are removed from the kettle on a chain belt they pass beneath a salter. Salt is applied at the rate of 1.5 to 2 pounds to 100 pounds of chips. The top of the kettle is covered with a stainless steel hood with one or two steam vent stacks for the removal of the large amount of water vapor which is driven from the slices by heat (Figure 2).

Fats and oils used – In this country the principal limpid oils used are cottonseed, corn and peanut. Hydrogenated vegetable shortening is used very extensively, in some areas almost exclusively. Soybean oil comprises a portion of the hydrogenated vegetable shortenings but is never used alone in this country. Animal fats are use practically not at all although deodorized, hydrogenated and antioxidant-stabilized animal fats could very well be used. In some countries oils such as saffron, palm, sesame, etc. are used primarily because of their availability and price. Antioxidants such as butylated hydroxytoluene, propyl gallate and others are added to cooking oils to retard development of rancidity in the oil and in the chips. Antioxidants also may be mixed with the salt and applied in that manner; they also may be atomized on the chips as they come from the fryer. Flavor of potato chips may be enhanced by applying monosodium glutamate mixed with the salt.

Rancidity also may be delayed and shelf life of chips extended by utilizing some or all of the following suggestions: (1) proper handling of fats and oils in the plant to avoid excessive aeration, overheating before use, contamination from copper or copper alloy pipes and fittings, etc. (2) filter the oil continuously or frequently to remove starch grains, chip fragments and other sediment, (3) have rapid turnover of fat in the kettle by reducing the size of the kettle and by frying for as long periods as possible, (4) add fresh oil to the kettle continuously to supplant that absorbed by the chips, (5) avoid aeration of fats when pumping it through filters, holding tanks, etc. to minimize deterioration of oil by oxidation, (6) avoid heating oil above 385° F. in an attempt to increase frying capacity of the kettle, (7) avoid intensely heated areas in the kettle resulting from poor placement of burners, poor circulation of oil, etc., (8) avoid contamination of fresh oil with spent or used oil and (9) avoid contamination with cleaning compounds caused by neglecting to rinse the cleaned areas well before reusing.

Inspecting and packaging chips – After being salted the chips drop onto a moving belt where they become cool and from which the low grade off color chips are removed and discarded. They may be placed in large metal or plastic containers until they are ready for packaging or they may move directly to the packaging machinery. In most large plants the chips are weighed automatically and dropped into packages for closure. Cellophane and waxed glassine packages are used about equally, however aluminum foil is widely used in Canada. Most packages are heat sealed automatically. The packages are tehn placed in cardboard cartons and sealed or stapled shut, ready for shipment.

FROZEN FRENCH FRIES AND OTHER FROZEN POTATO PRODUCTS[1]

IRVIN C. FEUSTEL AND RAY W. KUENEMAN[2]

GROWTH AND DEVELOPMENT OF THE INDUSTRY

The frozen potato products industry is reported to have begun in 1945 with the commercial freezing of French fries. Production of frozen French fries and other frozen potato products has since increased steadily from the initial volume of about 3½ million pounds to a total of over 219 million pounds during the 1956-57 crop year. About 9 million bushels of potatoes were used from the 1956 crops for processing into these products. Per capita consumption of frozen potato products is second only to peas among all frozen vegetables. The institutional pack was almost negligible prior to 1953 but this outlet expanded very rapidly and accounted for 43.3 per cent of the total pack in 1957.

A number of frozen by-products or co-products, such as patties, puffs, hash brown and mashed or whipped potatoes, has become associated with the production of frozen French fries. These products not only serve a very important purpose in utilizing small potatoes, slivers and short pieces of potato that would otherwise be wasted in the cutting operations but have also provided diversity and have contributed to the wide-spread popularity of frozen potato products. French fries comprise about 85 per cent of the total volume.

The variety of frozen potato products now available include: patties, mashed or whipped, dice, hash brown, shredded, baked stuffed, baked, boiled, rissole, au gratin, creamed, scalloped, delmonico, cakes, roasted, knishes, blintzes and cream of potato soup. New frozen products are being introduced from time to time. Among the more recent is a shredded and extruded deep fat fried product. Others are dehydrofrozen mashed potato and dehydrofrozen diced potato.

CONVENIENCE AND QUALITY OF FROZEN POTATO PRODUCTS

French-fried potatoes and other frozen potato products are becoming increasingly popular. Their convenience and dependability in quality makes a strong and effective appeal to the home consumer. Advantages for institutional users include [1] knowledge of exact cost, number of servings and cost per portion; [2] greater flexibility in meal preparation; [3] simplification of storage and inventory control; [4] receiving with a minimum of kitchen disruption; [5] uniform quality from one season to another; and, [6] reduced labor and time in preparation for serving.

PROCESSING QUALITY OF POTATOES USED FOR FRENCH FRYING

Variety of potato is considered to be the most important single factor influencing processing quality and those which are consistently high in solids content have generally proven best for processing.

Values for specific gravity (solids content) and reducing-sugar content, ease of conditioning after prolonged storage at 40° F., and results of frying tests are regarded as the most reliable guides in the selection of raw material for processing.

Influence of storage conditions. Potatoes are stored at 40° F. or

---

[1] This paper is an abstract of a chapter in the recently published book POTATO PROCESSING by W. F. Talburt and Ora Smith, published by the Avi Publishing Co., Westport, Conn.

[2] Fruit and Vegetable Marketing and Utilization Branch, Federal Extension Service, U. S. Department of Agriculture, Albany, California, and Food Products Division, J. R. Simplot Company, Caldwell, Idaho, respectively.

lower in many commercial storage cellars to minimize sprouting, withering and spoilage. Under these conditions, reducing sugars usually reach a relatively high concentration and the potatoes must be conditioned (held at 70° F. or higher for two or three weeks) to lower the sugar content. Some varieties or lots of potatoes will not condition satisfactorily.

Treatment of potatoes with chemicals that inhibit sprouting will permit storage at 50° to 55° F. and may thereby solve the problem of reducing sugar build-up since processing qualities usually remain relatively unchanged at these temperatures.

PROCESSING

Preparation of potatoes. Potatoes are peeled with lye or steam. Bruises, black spots, rotten portions, etc., are removed by hand trimming. Potatoes with serious defects are diverted for starch manufacture or for cattle feeding. Potatoes less than 1¼ inch in size are usually removed from the French fry line for processing into one or more of the by-products mentioned above. In some plants the largest potatoes (4 inches or over in thickness) are cut in half lengthwise to facilitate cutting into French fry strips.

Strip cutters used for making French fry cuts are designed for high speed operation. Slivers and short pieces or "nubbins" are separated from the product following cutting into French fries. A rotating reel or a vibrating screen provided with slots of proper size is used to eliminate the slivers. Similar types of equipment are used for removal of nubbins.

Blanching. The French fry strips are usually water blanched prior to frying. Advantages of blanching include [a] more uniform color of fried products, [b] lower fat absorption, [c] reduction in frying time, and [d] improved texture of final product.

Variations in time or temperature of blanching, or both are made on the basis of experience by processors to adjust to variations in the raw material. Common practice is to operate two blanchers in series for greater flexibility and more effective control of product color and texture.

Excess moisture is removed from the strips after blanching in order to reduce the load on the fryer and to minimize hydrolytic breakdown of the frying fat. The strips are passed over a dewatering screen and may be dried further with the aid of a stream of warm air.

Frying. The blanched potato strips are fed into the fryer at a carefully regulated rate. A draper type of conveyor is frequently used but some processors use specially designed equipment to carry the strips through the hot oil or fat. Careful control of frying time and temperature is essential to obtain a product which has the desired surface color and the proper internal texture.

Frying is a continuous operation using either one fryer or two fryers in series. The fat used is generally hydrogenated cottonseed oil. Temperatures are usually in the range of 350° to 375° F. Fresh fat is constantly added to the fryer during operation to replace that absorbed by the potatoes. This replacement is sufficiently rapid to maintain all the fat within the fryer in good condition under ordinary circumstances.

French fries produced for the restaurant or institutional trade, commonly referred to as par-fries, or oil-blanched potatoes, are less completely fried than is the product destined for the retail trade or home consumer. The par-fries are given a finish fry by the restaurant chef while the retail product is generally oven-heated in preparation for serving.

Excess fat adhering to the French fries is removed immediately after the product emerges from the fryer. One method of defatting is to pass the product over a vibrating screen and to allow the free fat to drain off. The

product is then air-cooled while being conveyed to the freezing tunnel.

Freezing and packaging. In most cases the French fries are loose frozen on a continuous belt in a freezing tunnel. The frozen product is packed for the retail trade in 9-oz. or 1-lb. cartons using a filling machine to fill to an approximate weight. Each carton is then usually weighed and final adjustment in contents made by hand. Five-lb. packages or bags are commonly used for the institutional trade. Blast or multiple-plate contact freezers are used in cases where the product is packed before freezing. Automatic carton filling and check-weighing equipment has been developed for packaging frozen French fries.

FROZEN POTATO CO-PRODUCTS

Potato patties. This is a versatile product that can be fried, baked, broiled, or prepared in other ways. It is produced from slivers and short pieces which are steam blanched and cooled and then shredded or chopped. Flour and seasoning are added. The product is formed into either a round or rectangular shape, then packaged and frozen.

Diced potatoes. This product is intended primarily for frying as hashed brown potato but may also be used in potato salad or for general purposes. The dice prepared from by-product material, are blanched and either loose frozen or packaged before freezing. Onion flavoring is added when desired by the customer.

Mashed or whipped potatoes. By-product material is diced and blanched then dewatered and cooked with steam. The cooked material is mashed and mixed with skim milk solids and salt. It may be passed through a finisher to remove lumps and fiber. The product is vigorously beaten for whipped potatoes. Products destined for use as mashed potatoes are also produced by freezing blanched and cooked slices or shredded potato.

Hash brown potatoes. Small whole potatoes are completely cooked, cooled, and shredded with special equipment. The product is packed in cartons before freezing. By-product material also serves for producing a hash brown product. This is shredded or diced followed by blanching and cooking.

Potato puffs. Another use for slivers and small pieces of potato is for the preparation of frozen potato puffs. The raw material is cooked with steam, mashed and mixed with wheat flour, eggs, vegetable shortening and seasoning. The mixture is usually extruded in the form of croquettes, allowed to cool and fried in deep fat.

Au gratin potatoes. A sauce consisting of milk, cheddar cheese, salt, monosodium glutamate, and pepper is combined with cooked diced potatoes in the approximate ratio of ⅔ potato to ⅓ sauce. Rice flour, shortening and sugar may also be added. A topping consisting of cheddar cheese, toasted bread crumbs, and margarine is sprinkled on the product in preparation for freezing.

Rissole potatoes. Small whole potatoes are blanched and fried in deep fat to a golden brown color.

Potato cakes. Beaten eggs and salt are thoroughly mixed with cold mashed potatoes or grated raw potatoes. Cakes are formed after mixing and dipped in fine bread, cracker crumbs or flour. The product is then fried in shallow fat. Midway through the frying the cakes are turned over for browning on both sides. The product is packaged after cooling.

Shredded potato. A new deep fat fried, shredded potato product was recently introduced. It is produced from small potatoes, slivers and broken pieces which are shredded, blanched and mixed with flour, salt, monosodium glutamate and spice. The mixture is extruded in the form of small "bite-size" logs and fried in

deep fat, then frozen and packaged.

Dehydrofrozen products. Dehydrofreezing is a relatively new method of food preservation. As the name suggests, the process consists of a partial dehydration followed by freezing. The weight may be reduced by at least one-half by dehydration without loss of quality. The resulting product has the advantage of savings in container, shipping, storage and handling costs. Dehydrofreezing has been applied commercially to mashed and diced potato as previously mentioned.

Precooked frozen dinners. Frozen dinners have become very popular in recent years. The variety of frozen potato dishes that have been prepared for inclusion in the dinners include most of the products that have already been listed. A number of these products are also prepared for military use in precooked frozen dinners in accordance with military specifications.

DEHYDRATED MASHED POTATOES – POTATO GRANULES[1]

Carl E. Hendel[2]

Potato granules are dehydrated mashed potatoes in powder form that can quickly be converted to mashed potatoes by mixing with hot or boiling liquid. They are a convenience food that may be expected to help the potato industry maintain and perhaps even improve its position in the face of increasing competition from the many other convenience foods now on the market.

First introduced into the United States about 1948 as a product for home use, and with military interest greatly stimulated in 1950 and succeeding years by the hostilities in Korea, potato granules have found increasingly wide acceptance. The sizeable expansion during the past year should bring capacity for the 1958-1959 processing season to about 75,000,000 pounds. At this capacity the industry will be using nearly 6,000,000 hundredweights of potatoes, or about 3 per cent of the potatoes used for food. Continued expansion is anticipated.

THE ADD-BACK PROCESS

Although a number of processes have been developed for the direct production of potato granules, none of them is in commercial use in the United States at the present time. The one used is the "add-back" process, in which cooked potatoes are partially dried by "adding-back" enough previously dried granules to give a "moist mix" which after holding can be satisfactorily granulated to a fine powder. The process is outlined schematically in figure 1. Following peeling and trimming, the potatoes are usually sliced (thickness about ⅝ to ¾-inch) to minimize non-uniformity of cooking. Cooking is in steam at atmospheric pressure, with the potatoes on a moving belt at a depth of about 6 to 8 inches. Mashing and mixing with the dry add-back granules is then performed, and the resultant moist-mix is cooled to approximately 60 to 80° F. It is then conditioned by holding for about one hour at this temperature, mixed, dried in one or two stages to about 12 to 13 per cent moisture content, and screened. Material coarser than about 60 to 80 mesh is returned to the process as add-back for succeeding

[1]A summary of a chapter by the same author in the recently-published book *POTATO PROCESSING*, edited by W. F. Talburt and Ora Smith, and published by the Avi Publishing Company, Westport, Connecticut.

[2]Western Regional Research Laboratory, Albany, California, a laboratory of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

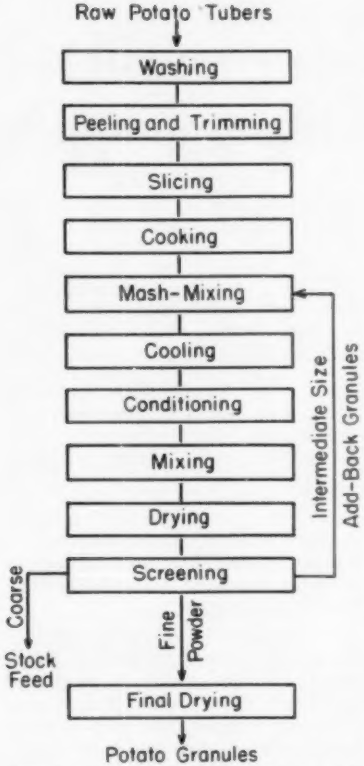


FIGURE 1.—Schematic outline of the add-back process for manufacture of potato granules.

cycles. A part of the fine material passing through the screen is also returned as add-back, but the part to be used as product of the cycle is further dried to a moisture content of about 6 per cent. About 12 to 15 per cent of the material is removed as pack-out; the remainder is used as add-back.

Although the principle on which the process is based is not complex, production of high quality potato granules is not an easy task. Since 1950, numerous improvements in techniques have resulted from efforts of the manufacturers and from those of several research institutions. Developments of one commercial concern have been reported by Kueneman and Havighorst (1). An extensive potato granule research program has been in progress at the Western Regional Research Laboratory during this period.

MANUFACTURING OPERATIONS

To minimize cell rupture and resultant pastiness due to release of free starch, all manufacturing operations are carried out as gently as possible. Special equipment, and methods of operating the equipment, for various steps in the process have been developed by each of the producing companies. Mashing is now usually by the mash-mixing technique in which the hot cooked potatoes are mixed with the dry add-back granules until an apparently homogeneous moist-mix is obtained.

Cooling of the moist-mix is effected gently in a shaker-cooler in which the product is passed over a vibrating screen of very fine mesh, through which cool air is passing.

Conditioning of the cooled moist-mix is usually on moving rubber belts about four feet in width and depressed at the middle to form a wide "V." Depth of product at the center of these belts is only about six to nine inches. Since some agglomeration occurs during conditioning, a gentle mixing is often employed at the end of the conditioning period. Fine granulation of the product is thus improved.

The product then goes to first-stage driers, where again every effort is made to minimize cell damage. Several kinds of driers are in use. After drying to about 12 to 13 per cent moisture content, the product is screened. The final drying of the pack-out granules or product of the cycle is carried out in a fluidized bed drier, shown schematically in figure 2. This drier consists of a chamber with a porous ceramic or very fine mesh screen bottom through which

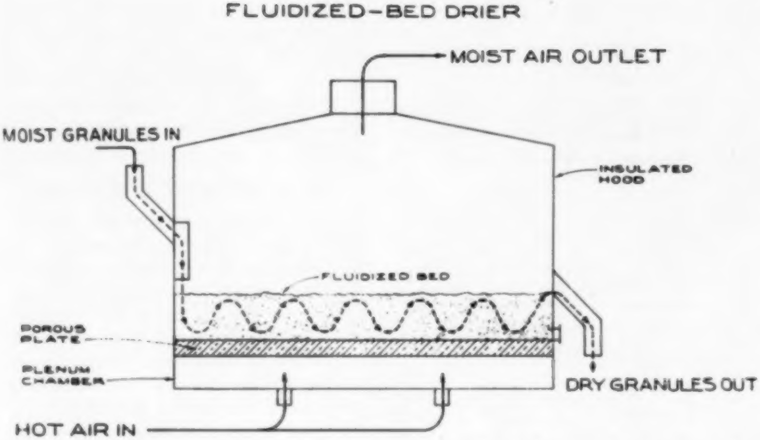


FIGURE 2.—Continuous fluidized-bed drier for use in finish-drying of potato granules (Neel *et al.*, (2).)

heated air flows. The granules, entering continuously at one end of the drier and leaving at the other, are suspended or fluidized by the air from the porous bottom of the bed. The granules offer no resistance whatever to lateral movement, flowing like a liquid. Drying occurs during the 10 to 30 minute residence time. The inlet air temperature can be quite high without scorching the product because transfer of heat occurs so rapidly that none of the granules reach a very high temperature.

STORAGE

Like other dehydrated potato products, potato granules are subject to two principal types of deterioration during storage: nonenzymatic browning and oxidative deterioration. Measures to control nonenzymatic browning are the use of potatoes of low browning tendency, use of sulfite, drying the product to low moisture content, and avoiding high storage temperature.

Oxidative deterioration is controlled or minimized by nitrogen-packing to reduce the oxygen content of the package atmosphere to a low level, and by use of antioxidants. Considerable research is in progress at the Western Regional Research Laboratory and elsewhere to develop better methods of maintaining shelf life of the product.

To summarize, continued growth of the potato granule industry is anticipated. Product quality is good, and cost is low, the latter resulting in large part from the moderate costs of packaging and shipping this high density product.

Indications are that potato granules – together with other processed potato products – will be of great value to the potato industry. Through their ability to compete effectively with other convenience foods, it is possible that the decline in consumption of potatoes per person can be permanently halted. Perhaps eventually consumption can actually be increased.

REFERENCES

1. Kueneman, R. W., and Havighorst, C. R. (1955). How to unit-engineer a line operation. Food Eng. 27 (5), 86-89, 118-121, 212-213.
2. Neel, G. H., Smith, G. S., Cole, M. W., Olson, R. L., Harrington, W. O., and Mullins, W. R. (1954). Drying problems in the add-back process for production of potato granules. Food Technol. 8, 230-234.

POTATO FLAKES[1]

RODERICK K. ESKEW[2]

A new type of dehydrated mashed potato in flake form is now in commercial production. The product is the result of the development at the Eastern Utilization Research and Development Division of the Agricultural Research Service in Philadelphia of a process, whereby cooked potatoes are very rapidly dehydrated on a drum drier under conditions that do not impair the flavor or texture of the reconstituted product.

The drying of cooked potatoes on single drum driers has been done for more than a half century to produce potato flour, but it was not until 1954 that Cording and Willard of the Engineering and Development Laboratory in Philadelphia showed how this effective drying mechanism could be employed to yield a product which could be reconstituted with hot water or milk to give a mash equal in texture to that of a freshly mashed potato. Their success can be attributed to careful control of all steps in the process to minimize rupture of potato cells, thereby minimizing release of free starch, and to the use of precooking and cooling steps to retrograde (reduce the solubility) of the amylose fraction of the starch.

The process is shown in figure 1. It consists of lye- or steam-peeling the potatoes, and after inspection and trimming, slicing them into one-half inch thick slabs. They are then precooked for twenty minutes in water at 160° F., followed by cooling to below 70° F. for at least twenty minutes. Cooking is in steam for twenty to fifty minutes depending on variety. The softened pieces are riced, additives are incorporated and the mash is dried on the surface of a heated drum to a parchment-like sheet, which is cut into pieces approximately one-half inch square.

The precooking and cooling steps are of great importance. They retrograde the amylose fraction of the starch, reducing its solubility and making less objectionable the small amount of free starch that inevitably results from processing. Raw potato slices so treated become translucent and rubbery requiring more cooking to soften them than untreated slices. The combination of precooking and cooling enables the use of potatoes of solids content of 18 per cent and sometimes lower; it improves the tolerance of flakes to boiling-water reconstitution, contributes good steam table life to the reconstituted mash and gives a built-in "abuse tolerance" to the product. Without these steps prior to cooking, good flakes can be made only from high solids potatoes. By employing precooking and cooling a wide variety of potatoes ranging in solids from 18 per cent to 24 per cent or higher can be employed commercially in flake manufacture. Among these are the following varieties from different areas:

California	Kennebec, Russet Burbank, White Rose
Idaho	Russet Burbank
Maine	Cherokee, Katahdin, Green Mountain, Kennebec, Russet Burbank
Maryland	Cobbler (Eastern Shore)
Michigan	Russet Rural, Sebago
Minnesota	Cobbler, Red Pontiac (Red River Valley)
Montana	Russet Burbank

[1]This is a summary of the chapter on Potato Flakes in the book Potato Processing by W. F. Talburt and Ora Smith, published by the Avi Publishing Co., Westport, Conn.

[2]Eastern Regional Research Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Philadelphia 18, Pennsylvania.

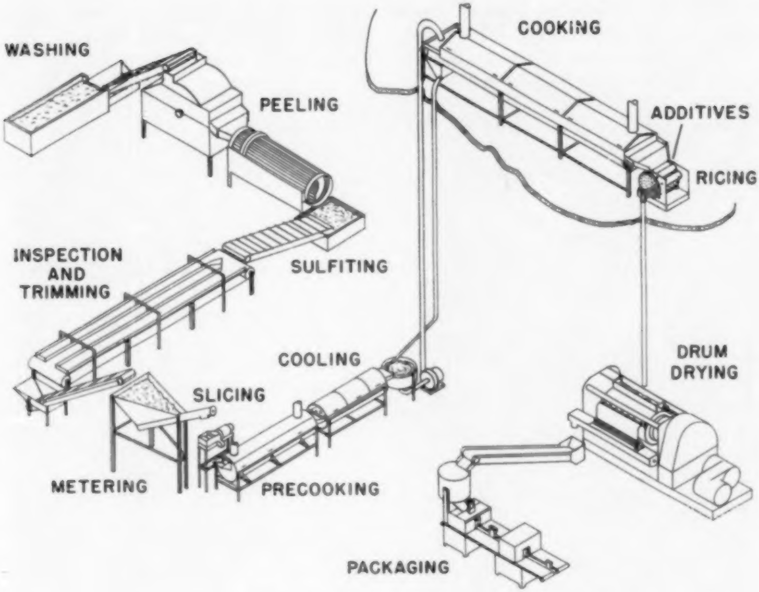


FIGURE 1.—Schematic design of potato flake process.

North Dakota	Russet Burbank (Walhalla), Cobbler, Red Pontiac
New York	Katahdin, Russet Burbank
Pennsylvania	Katahdin, Russet Rural
Washington	Russet Burbank
Wisconsin	Cobbler (Rhinelander), Russet Burbank (Antigo)

Thus, the manufacture of dehydrated mashed potatoes by the flake process need not be confined to high solids producing areas.

Cooking of the pretreated slices must be long enough to enable ricing with the minimum cell rupture. At sea level this may require anywhere from twenty minutes in atmospheric steam for Idaho Russets, to fifty minutes for Kern County White Rose. Overcooking may be conducive to poor texture.

The method used to reduce the cooked slices to a mash can strongly influence texture of the finished product. Tests with a variety of mashing devices showed that excellent results would be obtained with a ricer developed at the Philadelphia Laboratory and designed to preserve cell structure. It consists of a rotating perforated cylinder (¼ inch diameter holes) on the surface of which two small solid rolls are driven at the same peripheral speed as the drum. The clearance between the drum and the first roll is just sufficient to permit acceptance of the cooked slices and to crush them lightly. The second roll is set close enough to force the potatoes through the perforations. A ribbon screw inside the perforated cylinder, rotating in the opposite direction, discharges the product at one end.

Additives are desirably introduced before drying to improve flavor stability and texture. A mixture of sodium sulfite and sodium bisulfite is

used to give the equivalent of about 450 ppm based on solids in the mash. Much of this is lost in drying, but approximately 150 parts per million remain, corresponding to about 20 ppm in the product as consumed. The sulfite prevents change during processing and probably improves shelf life. Tenox IV* (0.37 per cent on solids basis) provides protection against oxidative rancidity. A small amount (0.1 to 0.7 per cent) glycerol monopalmitate is added to improve texture.

Drying is accomplished by applying the mash in successive stages to the surface of a heated drum. In this way a dense sheet is built up. When dried, it is about 0.010 inch thick and is continually cut into the desired size (usually ½ inch square) by a slitting roll followed by a transverse cutting roll, to yield the flakes of commerce. Drum drying is a very rapid and effective method of dehydrating. Only about twenty seconds are required to reduce the moisture from 80 per cent to about 5 per cent and, since most of this is accomplished in a partial blanket of steam, little opportunity is afforded for oxidative deterioration of the product. Moreover, at the low moisture level of the product, browning type reactions are retarded during storage. Oxidation changes are inhibited by the antioxidant. Hence, storage life in a tightly sealed package is approximately six months at room temperature. This can be extended to a year by using a nitrogen pack in addition to the antioxidant.

Potato flakes are now being manufactured in eleven plants in seven states as widely separated as Maine and Oregon. They are being sold for both home and institutional use. It is estimated that flake production this season will amount to about 50 million pounds.

*Reference to certain products does not in any sense imply an endorsement by the Department over others not mentioned.

FIGURE 2.—Potato flakes being manufactured in pilot plant of Eastern Regional Research Laboratory, Philadelphia, Pa. (*USDA Photo by M. C. Audsley.*)


QUALITY
BEGETS

DEHYDRATED DICED POTATOES

Ray W. Kueneman[1]

Dehydrated diced potatoes are becoming increasingly important in today's food industry. They afford manufacturers of food products and other users of potatoes the superior quality of Russet Burbank and other varieties of potatoes having high specific gravity. Dehydrated diced potatoes of uniformly high quality are available throughout the entire year in a number of sizes and shapes. They eliminate the need for high cost labor and equipment required for peeling, specking and slicing. Their usefulness in military feeding has been adequately demonstrated.

While drying, *per se* is one of the oldest methods for food preservation, acceptability of dried vegetables, including potatoes has been low until the last few years. Improved technology, production methods and machinery have revolutionized the performance and quality of the product to such an extent that a stable and expanding industry has been developed.

Dehydrated potatoes are used in a number of processed foods. Defense agencies procure substantial amounts for their use. Institutions are finding them useful in meeting their requirements for potatoes and to a limited extent they are now being packaged in small units for resale to the retail trade. One of the principle outlets is for use in canned meats, with canned corn beef utilizing the large part of the dehydrated dice now being produced. Canned stews also use this product. In canned corn beef the dice may be rehydrated and mixed with the beef before canning or they may be added dry and allowed to rehydrate during the retorting of the canned product. For products such as frozen meat pies or potato salads the pieces must be completely rehydrated with a minimum amount of disintegration before mixing with other ingredients as these products are not retorted. Diced potatoes procured for most military uses are cut quite thin so as to reduce rehydration and cooking time. Where used in mess halls and field operations they are served as buttered diced, hash browns and in a variety of other dishes such as casseroles. .

[1]Director of Research and Development, Food Processing Division, J. R. Simplot Company, Caldwell, Idaho.

RAW MATERIAL FOR DEHYDRATED DICED POTATOES

Color. The factor of color as influenced by the raw material to be used for dehydrated diced potatoes is exceedingly important. In general the fairly white fleshed varieties have proven to be more satisfactory than the yellow pigmented or the cream colored varieties often found in Europe and in limited areas in this country.

The raw potatoes should be free from any tendency to after cooking darkening or greying and should retain their white color in a stable form. This factor is usually influenced by certain physiological characteristics of the potatoes and the relationship of the enzyme system in these potatoes.

Another factor that may affect the color of the finished product is the reducing sugar content of the raw material and dehydrated diced potatoes should be produced from raw stock that is relatively low in reducing sugar content since this will produce a more uniformly colored finished product. Potatoes of high reducing sugar content will tend to produce a browner or even reddish colored finished product and this may change the color characteristics of the end product in storage. This is a very important factor in the storage or shelf-life of the finished product.

Other factors in raw material selection. In addition to the factors of color, total solids are exceedingly important from the standpoint of re-

covery in manufacture and end product performance. Varieties producing uniformly high specific gravity are most desirable and experience has shown that products from material of this classification have been the only ones to survive present day marketing conditions.

Potatoes should also be considered in terms of size, conformation to type, smoothness and freedom from secondary growth. Potatoes should be cut and examined internally for diseases such as necrosis and other pathological damage in various forms; insect damage, beetle stain, wire worm and other obvious defects. The cooking characteristics of the potatoes should be evaluated. Costly mistakes and unsuitable finished product can be largely eliminated by careful testing and selection of raw material.

Over a number of years one variety has been found to have a consistently high percentage of desirable factors outlined above. As a result of this, well over 90 per cent of dehydrated diced potatoes currently being produced in this country are being produced from the Russet Burbank potato. Its consistently high performance characteristics have made possible the rapidly expanding potato processing industry in Idaho. Those interested in the selection of other varieties would be well advised to use this variety as a yardstick for comparison. In addition it has good storage characteristics in fresh form.

MANUFACTURING

In general potatoes are washed thoroughly to remove any adhering soil and to reduce possibilities of contamination. Preliminary inspection follows washing to remove potatoes that are unfit for processing due to "light-greening," rot, mechanical injury or other serious defects. Following this inspection the potatoes are usually peeled with steam or lye. Following the peeling step, the potatoes are carefully washed, inspected and trimmed to remove any adhering blemishes. Following this procedure the potatoes are cut or diced into the many shapes that are now available to the market. Following dicing the potatoes are blanched to control the enzyme system present in the raw form. This is usually done by heating in steam or water at 200 to 212° F. Adequate methods for testing adequacy of blanching have been developed and are available. The degree of blanching also has a marked effect on the texture and appearance of the finished product as well as on the way the potato tissue dehydrates and reconstitutes. Considerable knowledge is available and the blanching techniques used are regulated by the end product performance desired in the finished potato dice. Gross under-blanching and over-blanching must be controlled to keep these factors under control. Blanching also reduces the microbiological population that builds up on the potatoes during the previous processing steps and is a substantial aid in producing a product of low finished bacteria count.

Sulfiting and calcium treatment. Various specifications are in existence calling for application of sulfite as SO_2 and/or the addition of calcium salts. These materials are added to control storage life of the finished product and also product performance when used by the ultimate consumer.

Present day methods of dehydration are the result of a tremendous amount of work that has been undertaken during the past years, especially since 1941. Currently most dehydrated diced potatoes are produced on conveyor type dryers. This equipment is very useful in that material handling costs are greatly reduced, loading and unloading are automatic and the system lends itself well to instrumentation and automation.

Continuous belt dryers allow the

product to be treated in different stages under different time and temperature conditions and subsequently provide conditions where the most optimum drying rates may be applied to ensure finished product performance. Drying rates have a decided influence on the finished product performance.

Following the dehydration step the potatoes are screened to remove small pieces to specification limits and are inspected, either manually or by the use of electronic sorters.

Packaging. There are few problems involved in packaging dehydrated diced potatoes. The military procurement in recent years has been limited almost completely to the No. 10 can, packed six to the case. Atmospheric packing is satisfactory and the No. 10 can has practically replaced the 5-gallon square can used to such an extent during World War II.

Dehydrated potato dice for remanufacture and other non-military uses are packed almost entirely in multi-wall Kraft paper bags ranging from 5 to 60 pounds in size.

The major uses for dehydrated diced potatoes are presently corn beef hash, frozen meat pies, Army rations, soups, potato salads and beef stews. Sizes are currently being produced from 3/16" x 3/16" x 1/4" cubes to the larger cuts of 3/4" x 1" x 3/8", depending upon the end product requirements.

Since dehydrated diced potatoes have many advantages including long shelf life, sandard costs of operation, adequate performance characteristics, they are increasing in favor especially with commercial users. Indications are that products of this type will soon attain sufficient performance characteristics to offer substantial advantages to institutional users and retail outlets as well. Product performance has been improved tremendously during the past year and the future is bright for these products.

CANNED AND PRE-PEELED POTATOES[1]

William F. Talburt and Carl E. Hendel[2]

1. CANNED POTATOES

Potatoes are canned in practically all of the major growing areas of the United States, with the industry most heavily concentrated in the early producing states. California and Maryland lead in the volume of potatoes canned. Approximately 60 per cent are produced west of the Mississippi River.

Slightly more than 3,000,000 cases of canned potatoes were packed in each of the last three years according to the best available statistics. The actual pack may have been substantially larger than is indicated by these figures since the production of many of numerous small packers may not have been reported. Potatoes in several different forms, including whole, diced, sliced, strips, and julienne, are processed. However, whole potatoes, usually smaller than 1½ inches in diameter, make up the greatest part of the potatoes that are canned.

Calcium-treating of potatoes is commonly practiced to firm the product to avoid sloughing during the heat processing. The firming effect is considered due to action of the calcium ion with constituents of the middle lamella to form calcium pectate.

Raw material requirements and selection. Potatoes are not grown specifically for canning; rather the smaller sizes not suitable for fresh market are used. In most instances, these potatoes are harvested, moved to packing sheds, separated from the larger sizes which go to fresh market, and are then transported directly to the canneries where they are processed within a few days. Under these conditions the processing season usually does not exceed 60 days and this is only a minor product for canneries producing other items. About the only exception to this method of handling is found in Maine where potatoes are canned from September 15 to June 15 as they are removed from storage cellars on their way to fresh market.

One of the primary requisites of a good canning potato is that it should not disintegrate or slough during processing. Immature potatoes with low solids content and with a specific gravity of less than 1.075 can generally be canned without disintegration or sloughing during processing even without the use of calcium salts. Sloughing can usually be prevented in specific gravity lots of 1.075 to 1.095, with the recommended amounts of calcium chloride. Potatoes with specific gravities in excess of 1.100 are likely to slough excessively even with added calcium salts.

As the harvest season progresses in a given area, maturity of the potatoes usually increases with a corresponding rise in specific gravity of solids. Generally greater sloughing is encountered as the season progresses until unsuitability of raw material necessitates termination of canning. This is not the case in Maine where the potatoes are generally fully mature before harvest. In the latter area, late storage potatoes that have become somewhat spongy are less subject to sloughing than those processed earlier in the season.

A flow sheet of the canning procedure is given in figure 1.

Cleaning. – It is essential that surface dirt be removed from the potatoes since it would damage the peeling equipment. Reel-type washers

[1] This material is a summary of chapters on "Canned White Potatoes" and "Pre-Peeled Potatoes" in the recently published book *POTATO PROCESSING*, by W. F. Talburt and Ora Smith, published by the Avi Pub. Co., Westport, Conn.

[2] Western Regional Research Laboratory, Albany, California, a laboratory of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

Flow Sheet for Canned White Potatoes

Raw Material Selection and Inspection
↓
Washing
|
Preheating (Optional)
|
Peeling
|
Inspecting
|
Size Grading*
|
Cutting
|
Filling
|
Brining
|
Sealing
|
Retorting
|
Cooling
|
Casing and Storing

*Size Grading is frequently done after washing

FIGURE 1.—Sequence of operations usually employed in the canning of white potatoes.

with strong sprays of water to loosen and remove adhering dirt are usually used. Where stones are a problem, they are removed by discharging potatoes from the washer into a trough with rapidly flowing water moving over a set of wooden riffles properly spaced at the bottom of the trough. The potatoes are carried along by the stream of water and any stones are caught on the riffles and remain behind.

Preheating. — In some plants potatoes are preheated in water prior to peeling in order to reduce the heat load on the peeler, thereby increasing its capacity. This operation is also said to be effective in preventing enzymatic discoloration and other darkening which may occur when potatoes are taken directly from cool storage and subjected to high temperature peeling.

Peeling. — Lye, steam, and abrasion peeling and combinations of these are used in the canning of potatoes. Both batch and continuous high pressure steam peeling equipment are used. Several types of lye peelers, including reel or drum types and draper belt in tank types, are in general use. Abrasion peelers are sometimes used by small processors where the size of the operation does not justify more expensive lye or steam peelers.

Inspection and trimming. — Only a minimum amount of trimming can be used on this low cost product. While some trimming to remove shallow eyes, small pieces of skin, and other defects may be advantageous, many canners feel that it is cheaper to sort these from the cleanly peeled potatoes and send them through the lye peeler again.

Size grading. — If potatoes have not been size graded before peeling, they are sized after inspection. Perforated belts and screens, rubber spools, and diverging belt graders are used in sizing potatoes.

Cutting. — Smaller sizes of potatoes are normally canned whole since they command a premium price. The larger sizes, 1⅞ inches to 2 inches or slightly larger, may be sliced. Still larger sizes are normally used for diced, julienne and shoe string potatoes.

Filling and packing. — Whole and cut potatoes are filled into the containers by automatic as well as rotary hand-pack fillers. Cans with plain inside hot dipped or electrolytic plate bodies and inside enamelled electrolytic plate ends are generally recommended.

After the potatoes have been filled into the container, either boiling water or brine containing 1.5 to 3.0 per cent of salt by weight should be added to the container in such quantity as to fill it to the proper level. Where boiling water is used, a salt tablet of proper size is added to the container prior to sealing.

The standards of identity for this product also permit the use of calcium, in the form of calcium chloride, calcium sulfate, calcium citrate, mono-

calcium phosphate, or any mixture of two or more of these salts. The amount of calcium salt used must be in such quantities that the total calcium content does not exceed 0.051 per cent of the net weight of the finished product. Calcium chloride is usually used because of its ready solubility. However, calcium citrate has been reported to impart less bitter taste to the product than does calcium chloride.

Abrasion peeling to remove part of the cooked gelatinized starch that is formed in high temperature lye or steam peeling allows more rapid penetration of calcium chloride and reduces the tendency of the potatoes to slough during subsequent processing.

Closing. – Closing temperatures of 160° F. or above should be maintained if ordinary closure is to be used. If the temperature drops below 160° F., steam flow or vacuum closure is used to obtain desirable can vacuum.

Processing. – Heat processing time ranges from 30 to 55 minutes at 240° F. depending on initial temperature and can size. At higher temperatures, the processing time is correspondingly shorter. Processing time is kept to a minimum to reduce sloughing.

Cooling. – After processing, cans are water-cooled promptly to about 100° F. Casing and stacking of the packed cans at temperatures in excess of 100° F. may result in the quality deterioration known as "stack-burning." If the temperature is much lower than about 100° F., the cans may not dry properly and external rusting of the containers may occur.

Federal regulations and grades. Canned white potatoes are covered by a standard of identity under the Federal Food, Drug and Cosmetic Act of 1938. Copies of the complete standards can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. Canners shipping interstate must comply with this standard as well as with state and local regulations for areas in which they operate.

United States Standards for Grades of Canned White Potatoes have been issued by the Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C. These standards for grades, which are not mandatory, describe in detail the factors considered in determining grades and the procedures for ascertaining the rating for each factor. These grades are quite widely used and serve as a basis for uniform quality description. Most purchases by Federal agencies are made on the basis of certified U. S. grade standards.

2. PRE-PEELED POTATOES

The twenty-five year old pre-peeling business is a relatively new and growing segment of the potato processing industry. Potatoes are peeled, treated with sulfite to prevent discoloration, refrigerated to arrest bacterial spoilage, and the pre-peeled product is delivered at the convenience of customers. The product is relatively perishable, but with care in processing and adequate cooling may be held for several days under refrigeration and excellent quality maintained.

Commercially pre-peeled potatoes are available in most metropolitan areas of the United States. A variety of forms such as Julienne strips for French frying, whole potatoes for general purposes, pre-cooked and shredded for hash-browned potatoes, and par-fried in deep fat for French frying supply the main demand at present in the food service industry. No substantial retail distribution has been developed although in many respects this appears to be a market of considerable magnitude that would allow a many-fold increase in the size of the industry.

Most pre-peeled potatoes are prepared in large well-organized process-

ing plants, using a force of hired labor and processing upward from 200 sacks of potatoes a day. Such plants are highly mechanized to reduce labor costs and have a number of delivery trucks to service customers.

Another type of plant which is also highly significant is the small family operation which may handle an average of 100 sacks of potatoes a day or less. In such operations, usually no labor is hired, or at most, only one or two permanent employees – the remainder of the labor being provided by the proprietor and his family.

Pre-peeling operations are generally located in or adjacent to the trade area that they supply so as to be within easy reach of customers.

The advantages to the food service industry inherent in the use of prepeeled potatoes are convenience and labor reduction in the handling and peeling of potatoes, elimination of waste and its disposal problems, assurance of high quality potatoes with minimum purchasing effort, and a relatively stable price for potatoes throughout the year. Pre-peelers are thus purveyors of service as well as of a product of uniform quality.

Raw material requirements. – The processor should test the potatoes before purchase for their suitability for the use intended. A minimum test would be to cut a representative sample of the potatoes into strips and French-fry them. If they fry to an unattractive dark color because of high sugar content, they cannot be used for this purpose. More elaborate tests would include flavor and color evaluations and a test for quality as boiled and mashed potatoes.

Peeling. – There are peculiar requirements for peeling in the prepeeling industry. In general it is not feasible to use peeling methods that involve use of heat if temperatures rise above the gelation point of starch, about 160° F. Abrasion and low-temperature lye peeling are the most widely used methods. In low-temperature lye-peeling, temperatures below 145° F. are used with lye concentration maintained at about 20 per cent. An integral part of a low temperature lye peeling operation is a well-designed washer for prompt and thorough removal of the lye-affected tissue. (Figure 2).

Trimming and Cutting. – At one time it was common practice to leave considerable peel on the surface of potatoes to be sliced for French fries. This practice has been largely abandoned in favor of completely trimmed French-fry cuts.

Hand-fed cutters are still in rather common use because they give a greater yield of the desirable long slices than do mechanical cutters. For a reasonably uniform product cut for French frying, 2 to 10 per cent of the peeled potato is removed in the form of undersized side cuts, slivers, and broken pieces.

Prevention of discoloration. – To date there has been no published information indicating that commercial color preservation of peeled potatoes has been accomplished without using sulfur dioxide or one of its salts as an active agent. In many cases where formulations of other reagents have been used in conjunction with sulfur dioxide, the effect has been to alter the degree of acidity of the solution into which peeled potatoes are dipped.

The use of sulfur dioxide or its salts is permitted by the Federal Food and Drug Administration, provided the preservative is not added to conceal damage or inferiority. Proper labeling is required when such foods are destined for interstate commerce. Most state and local governments follow Federal provisions relative to the use of sulfur dioxide. However, because exceptions exist, local offices of such agencies should be consulted prior to establishing a pre-peeling plant.

Immersion of the potatoes in the treating solution is usually in a tank

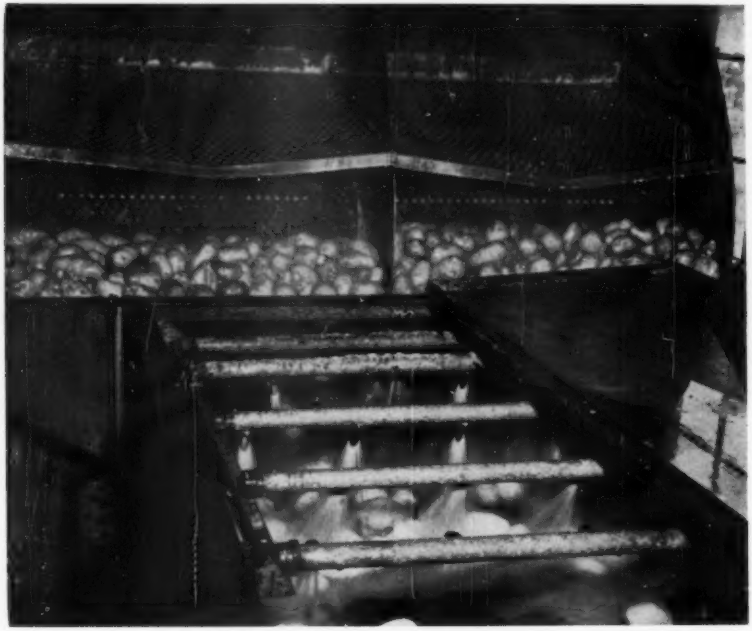


FIGURE 2.—Potato pre-peeling. White Rose potatoes emerging from wheel-type, low-temperature lye peeler and passing over scrubbing rolls in a washer.

with the potatoes on a draper belt which conveys them from one end of the tank to the other. Length of treatment is controlled by adjustment of speed of the belt. This provides one control over the amount of sulfite absorbed. Another control is provided by the concentration of the sulfite solution that is used. Increasing time and concentration give progressively increasing protection against discoloration. But they can also cause objectionable flavor, abnormal appearance, and leakage of cell sap from the cut potatoes. Thus, optimum treatment may represent a compromise between these several factors.

Refrigeration. – Low temperature is essential if discoloration and bacterial spoilage are to be controlled for adequate lengths of time. Storage temperatures between 32 and 40° F. are recommended . Even in this temperature range the product is perishable – perhaps more perishable than pasteurized milk. However, with proper treatment and reasonably sanitary precautions to prevent undue contamination at the time of processing, peeled potatoes may be held for 5 to 7 days at such temperatures without spoiling.

It is important that as much heat as possible be removed from the product before packaging because the removal of heat from a stack of packaged potatoes is very slow. Use of refrigerated treating solutions is very helpful, and can reduce French fry cuts to the needed cool temperature. It is not as effective with whole potatoes because of slower heat transfer through the larger units, but even here it is helpful. In the subsequent storage, adequate circulation around each package should be provided until the

FIGURE 3.—Potato pre-peeling. Packaging stand for French fry cuts. Partially stacked pallet of 30-pound bags of potatoes in foreground.
Photo by courtesy of Granny Goose Pre-Pared Potato Company, Oakland, California.

product temperature has been reduced to below 40° F. Delivery trucks should be well insulated or refrigerated to insure that the temperature of the product is below 40° F. when it reaches the customer.

Temperature must also be controlled after the product reaches the customer. Except for cases of very rapid use, the package should not be placed outside the refrigerator. If refrigerator space is not adequate, the customer should have smaller and more frequent deliveries to assure satisfaction.

Packaging. — A 30-pound or slightly smaller pack is most generally used for institutional trade. Bag type packages are most generally used but corrugated, waxed lined cartons have been used in some cases. Bags are usually of two-ply construction consisting of an outer Kraft paper bag with a polyethylene, high-wet-strength Kraft, or wax paper inner liner. (Figure 3)

POTATO FLOUR[1]

MILES J. WILLARD, JR. AND GERALD P. ROBERTS[2]

Potato flour is the oldest commercial form of processed potatoes, having been manufacured continuously in this country since before World War 1. It is widely used by the baking industry, both in this country and abroad and also finds use as a breading meal, and as a thickener for canned products, sauces, and dried soups. Potato flour is produced in this country in the Red River Valley and in Idaho.

The manufacture of potato flour is basically a simple dehydration process in which cooked potatoes are drum dried and pulverized. There have been no major changes in the method of manufacture since the drum dryer equipped with auxiliary rolls was developed in Germany in the last century.

Raw material for potato flour consists primarily of culls that remain afer the U. S. No. 1's and 2's are removed for fresh market and other uses. Under the recent diversion program of the U. S. Department of Agriculture, some graded potatoes were utilized in the production of potato flour. However, to make potato flour of high quality that is demanded by modern indusrty, only sound potatoes may be used. This means that a considerable amount of sorting and trimming must be done in order to up-grade the raw material.

STEAM PEELED

Steam peeling is the preferred method in most of the plants manufacuring potato flour today. Both continuous and batch type peelers are used. The washing and trimming steps are similar to those used in any other processing industry, with one exception. Because of the scalping action of the auxiliary rolls on the dryer, it is possible to tolerate a larger amount of peel remaining on the potato than in most other potato processing operations. The potato, however, must be trimmed free of all rot, green end, and other types of discoloration. Trimmings that are removed after peeling cannot be used for starch manufacture, as the starch has been partially gelatinized.

Continuous draper belts are now standard for cooking. Using steam at atmospheric pressure introduced above and below the potatoes, 45 minutes to one hour is required for adequate cooking of the potatoes.

The cooked potatoes are then conveyed or dropped to the top spreader roll of the single drum dryer. A screw conveyor is used on the top of this dryer to distribute the potatoes uniformly across the surface. An opening of 1/8 to 1/4 inch is usually desired between the three or four spreader rolls and the drying surface. The cooked mashed potato forms a coating on each spreader roll which in turn deposits the potato solids on the hot drum surface. Extremely rapid drying is possible with this equipment and evaporative rates of 18 pounds of water per hour per square foot of drying surface are common. A speed of 6 rpm and 100 pounds steam pressure gives a production rate of 5.25 pounds per square foot per hour when drying high solid potatoes. A dryer 3½ feet in diameter by 10 feet long will produce 14,000 pounds of dry material at 7 per cent moisture daily under these conditions. The dried sheet of potato solids is removed from the drum surface by a doctor knife held in contact with the drum. It is then normally fed by a

---

[1]A summary of a chapter by the same authors in the recently published book *Potato Processing* edited by W. F. Talburt and Ora Smith and published by the Avi Publishing Co., Westport, Conn.

[2]The Rogers Brothers Company, Food Products Division, Idaho Falls, Idaho.

screw conveyor to the intake of a fan and conveyed by air to the milling system. The thin flakes are comminuted in some form of beater or hammer mill and then screened to the desired size. Any remaining peel fragments are removed here. Two types of potato flour are common to the industry, granular potato flour and fine flour, screened through 7 XX cloth.

POTATO BREAD

Bakers have traditionally used peeled, cooked and mashed potatoes to impart potato flavor and improve retention of freshness in their bread. Potatoes have been long recognized as an excellent yeast food. Potato bread became common in Europe during the last century, and bakers who migrated to the United States from these countries brought with them the technology of potato bread production. The generally accepted level of potato flour in "potato bread" is 6 per cent. That is, 6 parts of potato flour are added to each 100 parts of wheat our. The largest volume of potato flour is used at somewhat lower levels in white, whole wheat and rye breads and buns. At levels of 2 to 3 per cent, it helps materially to preserve freshness due to the increased water absorption afforded by the potato flour. For example, when adding two parts of potato flour to the regular formula, two parts additional water may be added. Laboratory studies have shown that the absorption of water increases in direct proportion to the amount of potato flour used.

POTATO CRACKERS

The recent nation-wide introduction of potato crackers was an indication that the use of potato flour by the baking industry is not confined to bread alone. This special cracker, resembling a potato chip in texture and flavor, contains 12 to 20 per cent potato flour. The use of potato flour in soda, graham and other crackers offers a number of advantages, including more complete fermentation, greater volume and further flavor intensification. In addition, potato flour is used to advantage in pastries, donuts, cookies, cakes and prepared mixes.

There are several critical problems facing the manufacturer of potato flour today. In the processing of potato flour, a large proportion of the cost is represented by the price of the raw potatoes. In the baking industry where over 90 per cent of the flour is used, it is competing with lower priced wheat flour and other cheaper ingredients. A rise in potato costs would seriously jeopardize this industry. Another problem is the decline in per capita consumption of baked goods by consumers in the past years. The manufacturers of potato flour must develop improved products and find new markets in order to continue to maintain their growth.

NON-FOOD OUTLETS FOR POTATOES: STARCH AND FEED[1]

R. H. Treadway[2]

About 15 per cent of the annual potato crop is made up of sub-standard potatoes not suitable for the food market because they are too large, too small, damaged, or misshapen. Probably the most economical means of utilizing cull potatoes is to feed them to livestock on the farms where the potatoes are grown. Where the livestock population is insufficient, starch manufacture has proved to be the best method of using the culls. Since most of the potato starch is used for industrial purposes, it is entirely proper for starch to be considered in an article on non-food outlets.

POTATO STARCH

Background. Potato and wheat were the principal domestic starches early in the nineteenth century. The first potato starch plant in the United States was established in New Hampshire in 1831 at Antrim. By about 1880, more than 150 potato starch factories operated in the northeastern and in several north central states. In this early period, in Maine and other states, certain varieties of potatoes were grown especially for starch manufacture. These varieties were not outstanding in their culinary quality but had high starch content. In Holland and Germany, different varieties of potatoes are still grown for tablestock than for industrial use.

During the middle of the nineteenth century and somewhat beyond, starchmaking was one of the principal outlets for potatoes grown in the New England states. Except for this early period, however, potatoes have never brought a price at the starch factory that will support the cost of their production. Since the yield of starch is about one-tenth the weight of the potatoes ground, factory owners cannot pay more than about 35 cents per 100 pounds of potatoes and sell the starch for 6 to 7 cents per pound at the plant.. Notwithstanding the fact that potatoes to be used in starch production must be sold by the grower at a low price, starch making should be considered as an integral part of a healthy potato industry. Diversion of surplus and cull potatoes to the starch industry has done much to raise the quality of tablestock and establish a more orderly marketing in the potato industry, thus helping growers obtain a better price for the entire crop.

Late in the nineteenth century, potato starch lost its prime position in the general field to cornstarch, which became cheaper to make. Potato starch then came to be regarded as a specialty starch, preferred for certain uses. In the early years of this century, the number of potato starch factories declined and Aroostook County, Maine became the center of the industry.

In the recent period of the 128-year history of the American potato starch industry, an upsurge has occurred in the production of this starch. While the number of plants is not as large as it was many years ago, the newly constructed and modernized factories have a much greater total productive capacity. With the exception of four of the years, large amounts of starch were produced from each potato crop since 1940. Revival in the general usage

[1]Largely a condensation of the chapter "Potato Starch" from Potato Processing, by W. F. Talburt and Ora Smith, published by Avi Publishing Company, Westport, Connecticut (1959).

[2]Eastern Regional Research Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, United States Department of Agriculture, Philadelphia 18, Pennsylvania.

of potato starch has made it competitive with cornstarch, to a certain extent, in several applications. Nevertheless, it must be kept in mind that over ten times as much cornstarch as potato starch is used in the United States.

Potato starch production is limited to the northern states, where the late potato crop is stored throughout the winter and early spring. It is difficult to operate a plant economically unless potatoes are available over a period of about eight months each year. The operating season or "campaign" extends from about October 1 to about June 1 the following year, to total around 200 operating days. However, it is rare that the supply of cull potatoes is sufficient and evenly distributed so that the plants can operate at capacity throughout the season.

Statistics of production. There are 23 potato starch plants in Maine, with a total productive capacity believed to exceed 250 tons of starch per day. Total production of the Maine factories first reached the vicinity of 100 million pounds of starch per year in the 1950-51 campaign. The record high was set in the 1956-57 campaign with 115-120 million pounds being produced. Starch production was lower the following year due to a reduced supply of raw material but rebounded to a high level in the 1958-59 season because of the surplus crop.

Potato starch production in Idaho was started in 1941 when plants were established at Idaho Falls and Blackfoot. Additional plants were built subsequently until the total for Idaho is now 8. These 8 plants have a combined productive capacity of approximately 265 tons of starch per day, which is of the same order as that for Maine's 23 plants. The largest potato starch plant in the United States is at Twin Falls, Idaho, with a capacity of 50 tons of starch per day.

Two modern potato starch factories were built in the west in 1954-55 – one at Moses Lake, Washington and another at Monte Vista, Colorado. The Nation's newest potato starch plants are located at Riverhead, Long Island, New York and at Grafton, North Dakota.

Methods of production. Although potatoes present more problems in handling and storing than does corn, they are decidedly easier to process for starch recovery. Potatoes are ready for grinding immediately after leaving the washer. Either a hammer mill or rasp is used to disintegrate the potato cells and liberate the starch. Sulfur dioxide is added to inhibit discoloration due to enzymatic action. Skin and fiber are then separated from the starch by passing the diluted slurry through the screens. The pulp left on the screen is reground in many plants to recover more starch. The suspension of starch in water, which passes through the screens, is further purified to remove the soluble impurities and the remaining finely-divided insoluble impurities suspended in the "starch milk." Removal of the soluble impurities is effected by resuspending the starch in fresh water and letting it settle in vats or by letting the starch settle as the suspension flows slowly along channels called "tables." Many modern plants use centrifugals to wash the starch. The wash water containing the solubles is called "protein water." The fine fiber present in the starch milk is removed by passing the suspension through successively finer screens or is discharged in the "tailings" from the tabling or centrifugal separation. The latter two methods of separating fiber from starch depend on the fact that fiber has a lower specific gravity than starch and can be floated away while the starch settles.

The purified starch milk is dewatered by vacuum filtration or by centrifugation. The dewatered starch is dried by use of any one of several types of driers.

We might consider a typical Maine factory as grinding 80 to 90 tons of potatoes per day to produce about 10 tons of starch. It should have storage facilities for at least 6,000 to 7,000 hundredweights of potatoes. The process used in one Maine plant of this size is illustrated in figure 1. The flow diagram describes the various steps in processing. Although this factory is not of the latest type, its methods are efficient and the final product is of high quality.

The average composition of potatoes processed in Maine starch factories is estimated as follows, in percentages: starch 13; protein (N x 6.25) 2; cellulosic material 1.5; sugars 0.5; mineral (ash) 1; miscellaneous minor constituents (total) 1; water 81. Potatoes received at Idaho plants contain perhaps 15-16 per cent starch.

Fractions, modifications, and derivatives of potato starch. The fractions of starch, amylose and amylopectin, are imported from Holland for use in American industry. Uses of amylose are still largely experimental, but amylopectin is of established value in sizing and thickening. Most of the potato starch is sold in the native, unmodified form. However, sizable amounts are converted into dextrin by roasting and into pregelatinized starch. Modified starches having low paste consistency are produced by treatment with acids or oxidizing agents. Several chemical derivatives of potato starch are produced commercially, such as hydroxyethyl starch which is imported from Holland for use as a thickening gum.

Potato starch uses. Maine potato starch is used in the various outlets in approximately the following percentages of total usage: paper 60; textiles 30; food, adhesives, and miscellaneous 10. It is believed that potato starch produced in other areas is used in approximately the same percentages.

In recent years potato starch and cornstarch have sold in the same price range, with potato starch bringing much of the time 6 to 6½ cents per pound at the plant. Potato starch is well liked compared to the cereal starches because its pastes are comparatively clear, have strong adhesive and cohesive power, and have less tendency to set to a rigid gel on cooling. These properties are valuable for many applications in *paper manufacture*. Potato starch is used for (1) beater sizing; (2) tub sizing of the preformed sheet; (3) calendar sizing of quality paper; and (4) surface coating of high-gloss paper. The strong adhesive power of potato starch pastes also makes this starch in demand for *textile sizing*, particularly for "warp" thread being woven into cloth. Much potato starch is also used in the *food* industry, where it appears in bakers' specialty items, as a thickener in soups and gravies, and in "instant" puddings. Most of the potato starch used as an adhesive is employed in the form of dextrin. Potato dextrin paste is quite "tacky" and gives a flexible residual film that remoistens easily.

Starch outlook. This industry has made much progress in the past 15-20 years in furnishing consumers with higher quality starch and in adequate quantity. It is quite difficult to forecast how fluctuations in the size of future potato crops will affect the volume of starch production. Many leaders in the potato industry, though, predict that closer grading of food potatoes in the future will assure an ample supply of culls for starch manufacture.

LIVESTOCK FEEDING OF POTATOES

The exact quantity of potatoes fed to livestock each year is unknown, but it is perhaps 5 per cent of the crop on an average. The volume of potatoes fed to livestock is dependent on several factors, such as the supply available for an extended period, price of the potatoes relative to competing feedstuffs, and transportation costs

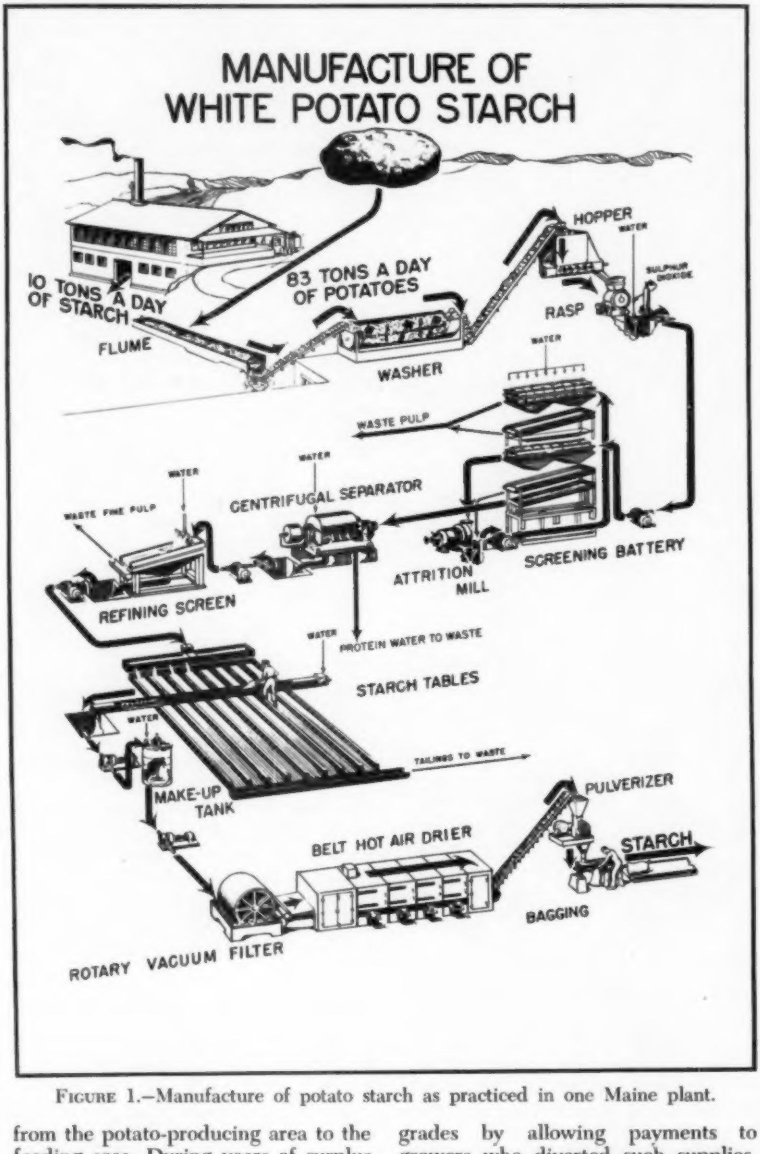


FIGURE 1.—Manufacture of potato starch as practiced in one Maine plant.

from the potato-producing area to the feeding area. During years of surplus potato crops, the United States Department of Agriculture has encouraged the feeding of certain lower grades by allowing payments to growers who diverted such supplies.

Potatoes are fed in combination with other feedstuffs to make a well-balanced ration. They are fed fresh

and in the ensiled and dehydrated forms that can be stored. Potatoes dried under conditions in which they lose but little juice are nearly equivalent to corn in feed value. Such dried potato feed (10 per cent moisture) contains typically about 75 per cent carbohydrate and 9 per cent protein (N x 6.25) and will replace about 4½ times its weight in fresh potatoes.

Potatoes are usually cooked before feeding to hogs, but they are successfully fed raw to cattle and sheep. Pigs are fed from 1 to 5 pounds of potatoes daily, the amount varying with body weight. Cooked potato silage and dried meal also are good feeds for swine. Steers and dairy cattle have been fed up to 60 pounds of fresh potatoes per day, the tubers usually being chopped or ground in advance. With lambs, potatoes are fed at the rate of 1 to 2 pounds daily per animal, along with legume hay and grain. Potatoes in various forms have been fed successfully also to turkeys, ducks, chickens, horses, and mules.

Although the ensiling of potatoes is not widely practiced at present, culls are dehydrated by natural means to produce dried feed in large tonnages. Sun drying of cracked potatoes spread on idle airport runways is a well-established method in Kern County, California. Natural freeze drying of potatoes spread on the ground during the winter months is satisfactorily practiced in North Dakota and Minnesota. Mechanical dehydration to produce potato meal is technically feasible but has not been extensively carried out commercially.

The extracted pulp from Maine potato starch factories is pressed and dried for sale as a feed component. This feed is high in carbohydrate but lower in protein than are whole dehydrated potatoes. In other areas the pressed pulp is fed in the wet form as received from the starch plant, or after ensiling.

In conclusion, the feeding of cull and surplus potatoes to livestock is an excellent means of utilization in locations where the animal population is adequate. Fresh, ensiled, and dehydrated potatoes are unquestionably of good value as feeds.

MISCELLANEOUS PRODUCTS FROM POTATOES[1]

IRVIN C. FEUSTEL[2]

Potatoes serve as a raw material for a number of industrial products as well as a great variety of food products which have been described elsewhere in this publication. Use of potatoes for production of alcohol and other fermentation products and for manufacture of a number of specialty food items are included in this section. Among the latter are several experimental porducts.

INDUSTRIAL PRODUCTS

Potatoes as raw material for fermentation. Potatoes are rich in starch which can readily be converted into fermentable sugars. However, fermentation of potatoes has never achieved any degree of commercial importance in the U. S. except for alcohol production during and immediately following World War II. Potatoes contain about 80 per cent water and are bulky and costly to transport and handle. Low grade potatoes, such as would be utilized for fermentation are also subject to spoilage unless dehydrated. Ordinarily, potatoes cannot compete with blackstrap molasses as a raw material. Synthetic processes for alcohol production using petroleum as a base also have significant economic advantages over potatoes. Europeans have long used potato alcohol in vodka and other liquors.

Potato broth is used by microbiologists as an ingredient of culture media for stimulating growth of various microorganisms. A similar product has also been used as a nutritional supplement in producing penicillin in Germany.

Canned potato salad. Two types of canned potato salad, a German type and an American or mayonnaise style are produced. The German style product consists of potatoes, bacon, onions and parsley in a sauce formulated from bacon fat, vinegar, water, seasoning and thickening agents. Mixing is usually a batch operation. The filled cans or jars may be processed in boiling water if the product contains sufficient vinegar. The product is commonly served as a hot dish.

American style potato salad as prepared by the housewife cannot be canned successfully because heat sterilization causes the salad dressing to separate and curdle. A specially treated or "boiled" salad dressing of low oil content must, therefore, be used. A waxy type of starch is also used as a base for the dressing to prevent setting up of the canned product during storage.

Canned corned beef hash and beef stew. Dehydrated diced potatoes are commonly used in these products. The dice are reconstituted by simmering in water about 15 to 20 minutes. A typical formula for corned beef hash includes onions, beef fat, sugar, salt and pepper in addition to the meat and potatoes. It contains about 45 per cent by weight of potato and not less than 35 per cent of cooked and trimmed beef. Canned beef stew usually contains carrots, tomato puree, and flour in addition to beef, potatoes and seasoning.

Potato soup. Potatoes used in canned soups are usually diced. Finely chopped onions or onion powder, milk, seasoning, butter, vegetable oil and flour are other ingredients.

Canned french fried or shoestring potatoes. Processing proced-

[1]This paper is an abstract of a chapter in the recnetly published book POTATO PROCESSING by W. F. Talburt and Ora Smith, published by the Avi Publishing Co., Westport, Conn.

[2]Fruit and Vegetable Marketing and Utilization Branch, Federal Extension Service, U. S. Department of Agriculture, Albany, California.

ures and equipment used for the manufacture of this product are similar to those used for producing potato chips. The potato strips are fried until the moisture is reduced to about 5 to 8 per cent. Excess fat is drained off after frying and salt is added. An antioxidant may also be added to increase shelf life.

Potato pancakes and pancake mixes. Traditionally, potato pancakes have been prepared from grated raw potato which is mixed with eggs, flour, onion, baking powder, salt and bacon fat. The batter is fried in hot fat until golden brown. A dehydrated potato pancake mix was developed in Germany during World War II. This product, when mixed with water, yields the batter for both potato dumplings and potato pancakes and can be used in other dishes. A variety of packaged dry potato pancake mixes have since become available. These are formulated from dehydrated potato, cereal flour or starch, salt, and in some instances onion and dried egg are included.

EXPERIMENTAL PRODUCTS

Potato chip bars. A potato chip bar was developed for military use by crushing potato chips and compressing them to about one-twentieth of their original package volume. The product was found to have excellent performance characteristics in terms of Quartermaster requirements for acceptability, nutritive qualities, storage life and convenience. The product was also indicated to have possibilities as a civilian snack item.

Potato "Nuts". Raw potatoes are diced (1/4 inch) and then fried in deep fat at 325° F. until the product has the desired color and texture for use as a snack food. The "nuts" may also be heated in an oven to drive out additional moisture without the necessity of frying until the pieces are excessively browned. The product is allowed to cool in a dry atmosphere before packaging.

Potato "Puffs". Potato pieces approximately 1/8 inch thick, 3/8 inch wide and from 3/8 to 1 inch long are blanched in boiling salt water. The blanched pieces are subjected to a high velocity, vertical, hot air stream in a special type dryer. This accomplishes rapid drying of the surface and at the same time heats the potato sufficiently high so that steam forms internally and expands each piece. The product is an oil-free, pillow-shaped toasted tidbit with an attractive crunchy texture.

Sponge-dehydrated potato. This product is prepared by cooking half-dice (3/16 x 3/16 x 3/8 inch) about 20 minutes in steam. The cooked pieces are cooled and frozen at −10° F., then allowed to thaw slowly for 12 to 16 hours. The thawed product is dried at about 130° F. to around 8 per cent moisture. It can be used for mashed potato by addition of hot liquid and is also considered suitable for use in soups, casserole dishes, chowder, hash, etc.

PRODUCTION OF CERTIFIED SEED POTATOES BY VARIETIES – 1959

Compiled by Orrin C. Turnquist

	Acres Entered	*Acres Passed*
ANTIGO		
Wisconsin	62.00	61.00
BLANCA		
Colorado	46.00	41.00
Nebraska	2.00	0.00
Total	48.00	41.00
BLISS TRIUMPH		
California	1.00	1.00
Maine	33.90	17.20
Minnesota	305.00	241.00
Montana	98.00	98.00
Nebraska	180.70	164.70
North Dakota	65.00	65.00
Oregon	10.50	XXX
South Dakota	217.00	217.00
Canada	68.50	61.00
Total	979.60	864.90
BOONE		
Maine	0.50	0.50
Nebraska	7.20	7.20
North Carolina	56.00	54.00
Tennessee	2.50	2.50
Wisconsin	4.00	4.00
Total	70.20	68.20
BURBANK		
Oregon	65.50	XXX
Washington	1.00	XXX
Total	66.50	XXX
CANSO		
Canada	105.75	XXX
Nebraska	89.50	59.50
Total	195.25	59.50
CAYUGA		
Nebraska	21.40	3.60
CHEROKEE		
Canada	91.21	80.00
Michigan	77.00	XXX
Maine	321.80	231.80
Minnesota	1,008.08	964.90
New York	12.00	12.00
Wisconsin	14.00	14.00
Wyoming	5.00	5.00
Total	1,529.09	1,303.20
CHIPPEWA		
Canada	185.46	180.00
Michigan	19.00	XXX
Maine	3,163.31	2,720.11
Minnesota	33.00	23.00
New Jersey	25.00	XXX
New York	234.00	234.00
North Dakota	1.45	1.45
South Dakota	4.00	4.00
Vermont	10.00	7.00
Total	3,675.22	3,169.56
COLUMBIA RUSSET		
Canada	75.60	75.00
CASCADE		
Oregon	0.50	XXX
DAZOC		
Colorado	53.00	53.00
Minnesota	120.75	96.75
Montana	3.00	3.00
Nebraska	274.30	274.30
North Dakota	39.00	38.00
Oregon	3.50	XXX
Washington	12.00	XXX
Wisconsin	10.00	9.00
Wyoming	14.00	14.00
Total	529.55	488.05
DELUS		
Maine	6.40	4.45
Michigan	8.00	XXX
Minnesota	0.10	0.10
New Hampshire	[100 lbs.]	
New York	9.00	9.00
Total	23.50	13.55
EARLY GEM		
Colorado	47.00	42.00
Idaho	206.00	206.00
Minnesota	123.60	123.60
Montana	26.00	8.50
Nebraska	144.30	144.30
North Dakota	950.60	869.60
Oregon	13.00	XXX
Washington	17.00	XXX
Wisconsin	662.00	638.00
Wyoming	56.00	45.00
Total	2,245.50	2,077.00
EARLY OHIO		
Canada	46.95	46.00
Michigan	12.00	XXX
Minnesota	476.60	476.60
North Dakota	287.00	287.00
South Dakota	36.00	36.00
Wisconsin	37.00	37.00
Total	895.55	882.60

XXX—acreage passed was unknown when table was prepared.

	Acres Entered	Acres Passed
EARLY ROSE		
Canada	6.25	6.00
Washington	1.50	XXX
Total	7.75	6.00
EXCEL		
Nebraska	30.20	25.20
GOLDEN CHIPPER		
Colorado	10.00	1.00
Michigan	38.00	XXX
Minnesota	35.50	35.50
Oregon	111.00	XXX
Washington	0.40	XXX
Total	194.90	36.50
GREEN MOUNTAIN		
Canada	3,297.76	3,000.00
Maine	474.46	431.50
Michigan	12.00	XXX
Minnesota	10.50	10.50
New Hampshire	41.00	41.00
New York	34.00	34.00
Vermont	47.00	47.00
Wisconsin	1.00	1.00
Total	3,917.72	3,565.00
HAIG		
Colorado	29.70	29.70
Nebraska	365.65	180.65
Wyoming	31.00	21.00
Total	426.35	231.35
HOUMA		
Maine	0.08	0.08
New Hampshire	1.25	1.25
New York	3.00	3.00
Vermont	3.00	3.00
Total	7.33	7.33
HURON		
Canada	188.20	185.00
Maine	1.00	1.00
Michigan	14.50	XXX
Minnesota	6.00	XXX
New York	2.00	2.00
Pennsylvania	5.00	0.00
Wisconsin	37.00	37.00
Total	253.70	225.00
IRISH COBBLER		
Canada	2,122.61	XXX
Colorado	43.30	41.00
Maine	2,722.70	2,635.48
Michigan	12.50	XXX
Minnesota	13,386.16	11,997.25
New York	30.00	20.00
North Dakota	1,933.00	1,483.00
South Dakota	110.00	110.00
Vermont	6.00	6.00

	Acres Entered	Acres Passed
Wisconsin	72.00	72.00
Wyoming	13.00	13.00
Total	20,451.27	16,377.73
KATAHDIN		
Canada	7,664.06	XXX
Colorado	91.00	80.00
Maine	65,580.24	49,954.49
Michigan	156.00	XXX
Minnesota	0.93	0.93
New Hampshire	8.00	8.00
New Jersey	35.50	XXX
New York	1,029.00	1,004.00
Oregon	3.50	XXX
Pennsylvania	255.00	240.00
Vermont	344.50	338.50
Washington	25.00	XXX
Wisconsin	267.00	247.00
Total	75,459.73	51,872.92
KENNEBEC		
California	386.00	380.00
Canada	6,525.22	XXX
Colorado	138.50	97.00
Idaho	147.00	137.00
Maine	6,058.80	5,270.35
Minnesota	2,187.88	1,799.63
Montana	14.00	6.00
Nebraska	33.00	33.00
New Jersey	5.50	XXX
New York	112.00	93.00
North Carolina	44.00	42.50
North Dakota	1,410.30	1,317.50
Oregon	590.00	XXX
Pennsylvania	5.00	5.00
South Dakota	152.00	145.00
Vermont	11.00	11.00
Virginia	0.50	0.50
Washington	375.00	XXX
Wisconsin	418.00	218.00
Wyoming	24.00	24.00
Total	18,637.70	9,579.48
KESWICK		
Canada	921.00	854.00
Maine	314.50	221.00
Michigan	7.50	XXX
New Hampshire	0.75	0.75
Wisconsin	14.00	XXX
Total	1,257.75	1,075.75
LA SODA		
Oregon	9.50	XXX
Wyoming	24.50	24.50
Total	34.00	24.50
MERRIMACK		
Maine	78.76	70.43
Michigan	16.00	XXX

	Acres Entered	Acres Passed
New York	2.00	2.00
Wisconsin	3.00	3.00
Total	99.76	75.43
NAVAJO		
Colorado	40.75	21.00
Nebraska	1.00	1.00
Total	14.75	22.00
NEW WHITE		
Minnesota	14.70	14.70
NORGLEAM		
Minnesota	4.00	4.00
North Dakota	24.00	24.00
Total	28.00	28.00
NORLAND		
Colorado	10.50	10.50
Minnesota	911.60	758.10
Montana	8.05	0.05
Nebraska	8.70	8.70
North Dakota	1,921.25	1,765.75
South Dakota	56.00	29.00
Washington	13.70	XXX
Wisconsin	29.00	29.00
Wyoming	70.00	70.00
Total	3,028.80	2,671.10
ONAWAY		
Michigan	135.50	XXX
ONTARIO		
Maine	346.00	239.50
Michigan	13.00	XXX
New York	127.00	127.00
Wisconsin	115.00	75.00
Total	601.00	441.50
OSAGE		
Minnesota	5.10	0.10
OSSEO		
Minnesota	7.32	7.32
PAWNEE		
Canada	1.00	1.00
PLYMOUTH		
Maine	211.94	204.66
Minnesota	10.00	3.50
Nebraska	2.80	2.80
New York	26.00	26.00
Pennsylvania	25.00	25.00
Wisconsin	108.00	108.00
Wyoming	1.00	1.00
Total	385.74	370.96
PONTIAC		
Canada	53.45	53.00
Delaware	40.00	40.00
Idaho	4.00	4.00
Michigan	10.50	XXX
Montana	31.50	31.50
Total	139.45	128.50

	Entered Acres	Passed Acres
PROGRESS		
Maine	15.00	15.00
Montana	1.00	1.00
Nebraska	156.90	146.90
Wyoming	8.00	8.00
Total	180.90	170.90
PUNGO		
Maine	541.05	512.80
Wisconsin	4.00	4.00
Total	545.05	516.80
REDBAKE		
Minnesota	0.50	0.50
Nebraska	8.10	8.10
Total	8.60	8.60
RED BEAUTY		
Minnesota	0.10	0.00
Wisconsin	10.00	8.00
Total	10.10	8.00
REDBURT		
Minnesota	9.00	9.00
REDGLO		
Nebraska	3.76	3.76
RED KOTE		
Minnesota	20.80	1.60
RED LASODA		
California	36.00	36.00
Colorado	587.80	307.00
Minnesota	1,010.60	950.60
Nebraska	2,082.94	2,031.94
North Dakota	1,742.45	1,398.25
South Dakota	477.00	390.00
Wisconsin	542.00	507.00
Washington	24.00	XXX
Total	6,502.79	5,620.79
RED McCLURE		
Colorado	2,295.50	1,900.00
Wyoming	14.00	14.00
Total	2,309.50	1,914.00
RED PONTIAC		
California	247.00	246.00
Canada	2,808.83	2,763.00
Colorado	347.40	235.00
Maine	20.00	20.00
Minnesota	11,449.95	9,943.70
Nebraska	271.56	256.56
New York	12.00	12.00
North Dakota	13,784.20	12,157.20
Oregon	66.50	XXX
South Dakota	746.00	578.00
Virginia	0.50	0.50
Wisconsin	877.00	570.00
Washington	76.50	XXX
Wyoming	168.00	156.00
Total	30,875.44	26,946.96

	Acres Entered	Acres Passed
RED SPORT TRIUMPH		
Minnesota	5.00	5.00
North Dakota	19.00	19.00
Total	24.00	24.00
RED TRIUMPH		
Minnesota	149.50	149.50
RED WARBA		
Canada	11.25	11.25
Minnesota	141.60	116.10
North Dakota	35.00	25.00
South Dakota	12.00	12.00
Wisconsin	70.00	70.00
Total	269.85	234.35
RURAL NEW YORKER		
Colorado	157.75	127.75
Michigan	40.00	XXX
New York	10.00	10.00
Total	207.75	137.75
RUSHMORE		
Maine	50.00	49.00
Minnesota	0.50	0.50
North Dakota	40.50	40.50
Wisconsin	20.00	20.00
Total	111.00	110.00
RUSSET BURBANK		
California	1,379.00	1,067.00
Canada	4,848.25	3,891.00
Colorado	669.00	619.00
Idaho	16,044.00	15,042.00
Maine	5,380.05	4,978.10
Michigan	18.00	XXX
Minnesota	1,298.08	1,211.11
Montana	2,646.00	2,403.63
Nebraska	21.00	14.50
North Dakota	289.00	265.00
Oregon	20.00	XXX
Washington	610.50	XXX
Wisconsin (†)	1,298.00	798.00
Wyoming (†)	41.00	41.00
(†)—Netted Gem		
Total	34,561.88	30,330.34
RUSSET RURAL		
Canada	76.00	70.00
Colorado	168.60	164.60
Maine	187.50	187.50
Michigan	524.00	XXX
Minnesota	13.00	13.00
New York	138.00	138.00
Wisconsin	10.00	10.00
Total	1,117.10	583.10
RUSSET SEBAGO		
Maine	83.50	77.50
Michigan	10.00	XXX
Minnesota	2.50	2.00

	Acres Entered	Acres Passed
New Hampshire	1.25	1.25
Wisconsin	494.00	454.00
Total	591.25	534.75
SACO		
Maine	14.00	14.00
New York	1.00	1.00
Total	15.00	15.00
SEBAGO		
California	29.00	29.00
Canada	20,239.84	19,093.00
Delaware	55.00	55.00
Maine	114.30	114.30
Michigan	606.00	XXX
Minnesota	32.50	27.50
New Hampshire	0.50	0.50
New York	324.00	324.00
North Dakota	143.00	143.00
Pennsylvania	107.00	107.00
Wisconsin	590.00	532.00
Total	22,241.14	20,425.30
SEQUOIA		
Canada	1.25	1.25
Maine	9.40	9.40
Michigan	13.50	XXX
North Carolina	61.00	0.00
Tennessee	12.00	11.30
Total	97.15	21.95
SHERIDAN		
Nebraska	3.50	3.50
TAWA		
Michigan	14.00	3.00
Minnesota	10.22	9.72
Nebraska	3.20	3.20
New York	6.00	6.00
Wisconsin	45.00	40.00
Total	78.42	61.92
TETON		
Canada	12.00	10.00
Maine	351.60	330.60
Total	363.60	340.60
WARBA		
Canada	510.95	463.00
Maine	41.50	41.50
Total	552.45	504.50
WASECA		
Canada	130.00	121.00
Minnesota	255.50	247.55
Montana	2.00	2.00
North Dakota	70.20	70.20
Wisconsin	15.00	15.00
Total	472.70	455.75

	Acres Entered	Acres Passed
WHITE CLOUD		
Minnesota	1.00	1.00
Nebraska	3.00	3.00
New York	2.00	2.00
South Dakota	2.00	2.00
Wisconsin	12.00	12.00
Total	20.00	20.00
WHITE ROSE		
California	3,071.00	2,964.00
Canada	171.60	167.00
Idaho	115.00	115.00
Maine	38.00	38.00
Minnesota	17.70	17.70
Montana	158.00	150.00
Nebraska	9.00	9.00
North Dakota	275.20	269.60
Oregon	600.00	XXX
Wisconsin	18.00	18.00
Washington	838.50	XXX
Total	5,312.00	3,748.30
YAMPA		
Colorado	3.00	3.00
Minnesota	5.20	5.20
Total	8.20	8.20
OTHER VARIETIES		
BOUNTY		
Nebraska	87.96	87.96
Wyoming	1.00	1.00

	Acres Entered	Acres Passed
Misc. Seedlings		
Nebraska	12.20	12.20
RED SKIN		
New Jersey	5.00	XXX
LASALLE		
Oregon	1.50	XXX
FUNDY		
Canada	197.81	181.00
AVON		
Canada	39.71	35.00
EARLY EPICURE		
Canada	25.75	20.00
GOLD COIN		
Canada	15.75	14.00
MANOTA		
Canada	15.00	15.00
McINTYRE		
Canada	9.00	7.00
CANUS		
Canada	7.60	7.00
ARRAN VICTORY		
Canada	3.00	3.00
MOHAWK		
Canada	1.00	1.00
WEE MacGREGOR		
Canada	0.50	0.50
GARNET CHILI		
Canada	0.10	0.10
LaSALLE		
Wisconsin	2.00	2.00
TRIUMPH		
Wisconsin	2.00	2.00

NUTRITIVE VALUE OF POTATOES

H. D. Brown[1]

Due to its ready availability, low retail cost and overall nutritive value the Irish potato is one of the best, if not the best human food of semi-tropical and colder regions. The fact that its average annual world production is over 3,306 million cwt., greater than any other human food (2), is in itself evidence of its intrinsic food value.

Besides being a cheap source of calories (only sugar of the common foods is cheaper) potatoes furnish many of the vitamins, minerals and protein, including most of the essential amino acids. In fact, with the possible exception of fat-soluble indispensable nutrients, potatoes contain practically all essential dietary factors (18).

CALORIES

Although the caloric values of foods are largely discounted in the United States at present, a minimum intake is none the less essential. Table 1 prepared by J. B. Brown (6) depicts the relative cost per 3000 calories of 9 important foods. Sugar, which contains no nutrients, other than carbohydrates and margarine, which contains Vitamin A and some essential fatty acids, are the only foods which offer food economies comparable to potatoes. The fact that potatoes also provide a number of vitamins, minerals and small quantities of all the essential amino acids (18) places them in a class all by themselves at the top of the list so far as human nutrition is concerned.

Table 2, also by J. B. Brown (6), depicts the nutritive value of potatoes as commonly prepared, assuming a daily consumption of ⅓ pound per capita.

Though the fat content varies greatly according to method of preparation, it is essential to be realistic in appraising human acceptance. It is well known for example, that potato chips containing less than 31 per cent fat or oil are unacceptable (10). It is not an uncommon sight to see consumers add from one to three or more patties of butter (45 calories per patty) to baked potatoes or add an equivalent amount of calories as gravy, butter or cream to mashed, boiled, parsleyed or even hash browned potatoes.

It would be interesting to try to develop acceptable seasonings for potatoes which would not add calories. Such seasonings, obviously must be acceptable from the flavor standpoint as well as from the more elusive sense of touch factor (i.e. swallowing). It might also be advisable to stress the fact that acceptance of less highly seasoned foods, including potatoes, can be achieved with a little forbearance.

STARCH

Starch is the principal constituent of the dry matter content of the potato. Dry matter contents vary from 16.1 to 29.08 per cent according to Goldthwaite (7) and Heinze et al (8). The same authors found the starch content to vary from 10.2 to 19.14 per cent, although Brautlecht and Getchell (5) reported a variation of from 8 to 28 per cent. Goldthwaite (7) lists some observations which obviously apply to all chemical analyses of potatoes. [a] No two tubers have an identical composition. [b] The size of tuber is no criteria of maturity. [c] The dry matter, starch, total carbohydrates and ash are greater in the cortex than in the corresponding medullary area. Sharma et al (14) have recently mapped the differences in the density of the

[1]Research Coordinator, Potato Chip Institute International, 946 Hanna Building, Cleveland, Ohio.
Dr. Brown died shortly before publication of this Handbook.

TABLE 1.—Relative Cost of Some Staple Foods, Including Potatoes on a 3000 Calorie Energy Basis. Other Principal Nutrients Provided by These Foods.*

Foodstuff	Cost lb.	Calories lb.	Cost per 3000 Cal.	Other Nutrients
Sugar	$0.11	1800	$0.18	None
Potatoes	0.03	325	0.27	B-vitamins; vit. C; minerals; some good protein
Margarine	0.30	3300	0.27	Fat; vit. A
Bread (Enr.)	0.16	1254	0.38	Protein; B-vitamins; minerals
Butter	0.70	3300	0.63	Fat; vitamins A and D
Milk	0.12	309	1.18	All nutreints; low in vit. C and iron
Cabbage	0.05	80	1.85	B-vitamins; vit. A and C; minerals
Turnips	0.10	126	2.38	V-vitamins; vit. C; minerals
Hamburger (Round)	0.80	830	2.88	Protein; B-vitamins; phosphorus; iron

*From J. B. Brown (6)

TABLE 2.—Nutritive Values of Potatoes (Based on Estimated Consumption of ⅓ pound per Capita per Day in the U.S.)*

Potatoes served	Cal.	Prot. (grams)	Fat (grams)	Carb. (grams)	Ca mg.	P mg.	Iron mg.	Vitamins A iu.	Vitamins B_1 mg.	Vitamins B_2 mg.	Vitamins Niac. mg.	Vitamins C mg.
Baked*	150	3.6	0.2	33	20	100	1.1	30	0.6	0.07	2.1	25
Mashed	122	3.3	1.0	25	41	96	0.9	60	0.12	0.08	1.2	10
Boiled*	124	3.0	0.2	28	17	84	1.0	30	0.14	0.06	2.1	25
Fried (H.B.)†	362	4.9	16.0	48	31	159	1.8	45	0.12	0.09	2.6	11
Chips‡	816§	10.1	56.0	75	45	224	3.0	75	0.27	0.16	4.8	17
Rec. Allow.	3000	70	?	?	800	1500	12.0	5000	1.5	2.0	15.0	75

*% of total calories as fat, 1.5
†% of total calories as fat, 40
‡% of total calories as fat, 61
§Over 500 of these 816 calories are from fat.

Note: Values for "Fried" and "Chips" above are not strictly comparable to those preceding because non-potato ingredients are included and because, for example ⅓ lb. potato chips represents much more than ⅓ lb. of original potatoes.

*From J. B. Brown (6)

different portions of potatoes. The pith had a lower specific gravity than the "cortical" tissue in all of 14 varieties tested.

The specific gravity can be used in predicting the total dry matter content of tubers (8). Correlation coefficients ranging from a low of 0.637 to 0.972 have been secured by different research workers. (8) Correlations between specific gravity and starch and between specific gravity and alcohol insoluble solids were almost as good (8).

High starch potatoes are mealy, dry and slough extensively. They are usually rated as superior in flavor but starch has no significant effect on color (8).

The starch content of tubers increases during growth (4) usually reaches a maximum when approximately two thirds of the foliage is dead and decreases slightly during storage (8). It varies greatly among varieties, grower (7), season, locality (8), but not appreciably due to irrigation (7) provided over-irrigation is not practiced. Although it is difficult to prove from any one set of experiments, it is more than likely that high starch content is produced in years and regions when sunshine is adequate, when temperatures for the

most part do not go much above 83° F. and where the length of day is adequate for most of the growing period to produce a large vegetative growth and then shorten to insure carbohydrate translocation to the tubers. In short, starch content, as well as high yields, are probably regulated by the accepted length of day and carbohydrate-nitrogen concepts.

Dry matter and alcohol insoluble solids (AIS) are both closely related to starch and need not be discussed in detail. Correlation coefficients between these substances and attributes of quality, *i.e.* sloughing, color, dryness, mealiness and flavor are all approximately the same as for starch (8). Furthermore multiple correlation coefficients including several of these compositional factors are only 5 to 8 per cent above the highest coefficients for the single coefficients (8).

SUGARS

Sugars, especially reducing sugars are of special interest because reducing sugars in excess of 0.2 per cent cause undesirable darkening of potato chips and similar potato products prepared by deep fat frying. Furthermore an excessively sweet Irish potato is not acceptable to most consumers. For fresh consumption this undesirable flavor does not usually become apparent until the sugar content increases considerably above the quantity present at harvest time (8). Storage for short periods below 40° F. or for several weeks below 50° F. will induce undesirable reducing sugar accumulations. Total sugars of 6 varieties from 10 localities varied from .03 to 2.64 and reducing sugars from 0.02 to 1.46 per cent before and after 6 months' storage at 40° F. (8)

Green Mountain and Triumph varieties are high in total and reducing sugars though the varieties Cobbler, Katahdin and Russet Burbank accumulated much less (8).

High sugar content is only slightly associated with undesirable color of boiled, mashed or baked potatoes. High total or high reducing sugars generally produce poorer flavors, less mealiness, less sloughing, and less dryness (8). For French fried potatoes there is a high negative correlation between reducing sugars and color (–.982) and flavor (–.929) (9). No other highly significant correlations were found. However, reducing sugars were negatively correlated with specific gravity (–0.560) and with dry matter (–0.555). The White Rose from California with a specific gravity of 1.06 had reducing sugar contents ranging from 0.350 to 0.650 per cent though Irish Cobbler from North Carolina with a specific gravity of 1.07 had reducing sugar contents ranging from 0.050 to 0.200. The data, though not statistically significant, indicate a difference in specific gravity between varieties. Sebago and Triumph varieties that grew in Alabama and South Carolina did not show any differences in reducing sugars due to locality (9). As previously indicated the reducing sugar content depends largely on temperatures.

According to Schwimmer et al (13) fructose was more responsive to temperature changes than glucose or sucrose. Traces of other sugars were found. These include ketoheptose, melibiose, melezitose and raffinose. A fructan and some inositol were also found. They conclude that the presence of heptulose "points to the operation of the oxidative pathway of carbohydrate metabolism and to its possible involvement in sucrose transformations."

PROTEINS

Woodward and Talley (18) have presented an excellent review of the food value of the nitrogenous constituents of the potato. Table 3, taken from their publication shows that all the essential amino acids are furnished by the potato and the proportion of the daily needs that can be secured from an average daily

TABLE 3.—Essential amino acids supplied by average daily ration of potatoes.*

Amino Acid	Amount in 130 Gms. Whole Potatoes, Grams	Minimum Daily Requirements, Grams	Per cent Minimum Daily Requirement
L – Tryptophan	0.02	0.25	8
L – Phenylalanine	0.135	1.10	12
L – Lysine	0.125	0.80	16
L – Threonine	0.093	0.50	18
L – Valine	0.120	0.80	15
L – Methionine	0.05	1.10	4-5
L – Leucine	0.115	1.10	14
L – Isoleucine	0.093	0.70	13

*From Woodward and Talley (18)

ration of 130 grams of potatoes. Though the potato, containing but 0.24 to 0.36 per cent nitrogen on a fresh weight basis, and furnishes but 4 to 18 per cent of the essential amino acid needs in the United States the proportion increases to from 16 to 72 per cent in Belgium, France and Germany where the per capita consumption is approximately 400 pounds as compared to 100 pounds in the United States.

Woodward and Talley (18) further conclude: [a] Nitrogen from the potato, weight for weight is as efficient as that of wheat. [b] There is a complimentary action between the protein and non-protein nitrogen of the potato. Heinze et al (8) conclude "It is seldom that the protein and non-protein nitrogen fractions occur in as nearly equal quantities as they do in potato tubers."

Potatoes containing relatively high nitrogen contents exhibit less sloughing, are less dry, and less mealy when boiled, mashed or baked. The flavor of high nitrogen potatoes was also slightly less acceptable (8). Stuart and Appleman (15) state that the nitrogen distribution of Irish Cobbler and McCormick potatoes, at 2-3° C., remained remarkably stable for storage periods up to five months, but Heinze et al (8) found stored potatoes to be definitely less palatable. They conclude that this lack of flavor acceptance may be due to the non-protein nitrogen. Since Stuart and Appleman (15) found a slight hydrolysis of protein on storage resulting in a percentage decrease of protein nitrogen (dry wt. basis) and an increase of non-protein nitrogen, it is conceivable that the non-protein nitrogen may in fact be responsible for off flavor.

Although data (8) indicate differences due to variety and locality they are too meagre to permit generalizations. It is rather apparent nevertheless that the protein and amino acid values of the potato are significant and should be given greater emphasis.

One possible reason for the lack of proper credit may be due to the difficulty of extracting the basic amino acids for chemical analyses (16). Thus the lysine contents as commonly reported have obviously been somewhat low.

VITAMINS

The quantities of important vitamins secured from ⅓ pound per day of several different forms of potatoes are shown in table 2 and the per cent spent in the United States for potatoes and values received in the form of vitamins are shown in figure 1.

It is obvious that potatoes are an important source of ascorbic acid, niacin, thiamine (B_1) and riboflavin (B_2).

Ascorbic acid. Vitamin C (ascorbic acid) is the most abundant and most variable of the vitamins in potatoes. Leichsenring et al (11) have published comprehensive data relative

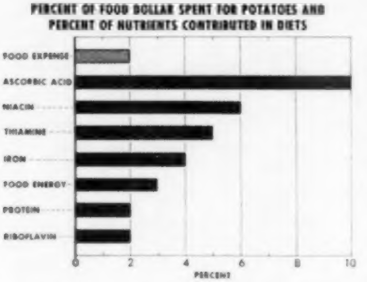


FIGURE 1.—Estimated average cooking losses have been deducted. Source: Unpublished data on a 1955 Food Consumption Survey, Household Economics Research Division, Institute of Home Economics, U. S. Department of Agriculture.

to factors affecting the Vitamin C contents of raw and prepared potatoes. They found that the reduced ascorbic acid values for tubers of different varieties varied from 6.2 to 64.0 milligrams per 100 grams on a moist weight basis. However, these values must not be considered final as different analytical procedures were used by different workers. Furthermore the dehydroascorbic acid values were frequently not determined. The dehydroascorbic acid values varied from 1.2 to 3.6 mg. per 100 grams on a moist weight basis for a very limited number of tests. Average values for ascorbic acid are given in table 2. It is obvious that oxidative losses occur during preparation for consumption. It is most likely that the great variations in the Vitamin C content of the raw tubers is associated, as is the carbohydrate content, with sunshine and respiration with other environmental factors playing a minor role. Leichsenring et al (11) found significant differences in ascorbic acid contents due to varieties and to crop years.

Thiamine. Thiamine (B_1) values varied from 0.068 to 0.142 mg. per 100 grams moist weight basis for a very limited number of analyses (11). Thiamine content increases slightly during storage. This is probably due to a concentration of B_1 through moisture loss. The effect of environment upon the content of B_1 in the tubers is inconclusive. From table 2 it is obvious that B_1 is very stable as the content of potato chips is double that of any other prepared potato product.

Niacin. Niacin values (moist weight basis) for one sample only was 1.0 mg. per 100 grams for raw, 1.50 for boiled, 1.76 for mashed after boiling and 2.14 for hashed brown potatoes. Obviously the niacin is not destroyed by cooking. The higher values of the cooked potatoes can be attributed to concentration of the niacin by dehydration (11). The average niacin contents of commonly prepared potato products are shown in table 2.

Riboflavin. The average riboflavin (Vitamin B_2) contents of prepared potatoes are shown in table 2. Although the quantities are small it is obvious that this vitamin is also very stable since the highest value is in the highly dehydrated potato chips.

MINERALS

The potato is also an important source of calcium, phosphorus, and iron as can be seen from table 2. All are stable and all are concentrated in potato chips through dehydration. Ng et al (12) reported a calcium variation of from 20 to 62 mg. per 100 grams (dry weight basis) in potatoes which grew at Wooster, Ohio in 1955. They also found that a high calcium content in raw potatoes was associated with high total solids of tubers, and light colored chips and low fat absorption of chips.

The iodine content of tubers varies from 0 to 544 parts per billion on a fresh weight basis, being very low in goitrous areas and relatively high in areas free from goitre (3). If we accept 100 micrograms (100 p.p.b.) as the daily human need for iodine it is obvious that the consumption of ⅓ pound of potatoes form the goitre free

areas would supply nearly four times (380 p.p.b.) the daily needs of iodine. This is an important consideration since it is known that in spite of all educational programs the incidence of endemic goitre is 2-3 per cent in the goitrous areas of the United States.

In conclusion it is rather obvious from the foregoing that potatoes in their various forms afford suitable foods for almost every dietary need at a minimum of cost. Moreover because of the very high per acre yields they can be depended upon to take care of many years of population increases.

Literature Cited*

1. Anonymous, 1957. Potatoes, facts for consumer education. AIB No. 178, U.S. Dept. of Agriculture.
2. Anonymous, 1958. Foreign crops and markets. World Summaries.
3. Anonymous, 1952. Iodine content of foods annotated bibliography 1825-1951. Chilean Iodine Educational Bureau, Stone House, Bishopgate, London.
4. Appleman, C. O. and E. V. Miller, 1926. A chemical and physiological study of maturity in potatoes. J.A.R. 33: 569-577.
5. Brautlecht, C. A. and A. S. Getchell, 1951. The chemical composition of white potatoes. Amer. Potato Jour. 28: 231-250. 54 ref.
6. Brown, J. B., 1958. Observations on nutritional values of potatoes. Nat. Potato Council News 9th An. Meeting.
7. Goldthwaite, N. E., 1925. Variations in the composition of Colorado potatoes. Colo. Agr. Exp. Sta. Bul. 296.
8. Heinze, Peter H., Mary E. Kirkpatrick, and Elsie F. Dochterman, 1955. Cooking quality and compositional factors of potatoes of different varieties from several commercial locations. U.S. Dept. Agr. Tech. Bul. 1106.
9. Kirkpatrick, Mary E., Beatrice M. Mountjoy, Linda C. Albright and P. H. Heinze, 1951. Cooking quality, specific gravity, and reducing sugar content of early crop potatoes. U.S. Dept. Agr. Cir. 872.
10. Ledden, James, 1958. Investigation of desirability and methods of producing low fat in potato chips. Proc. P & T Div. Nat. Potato Chip Inst. p. 42-43.
11. Leichsenring, Jane M. and many others, 1951. Factors influencing the nutritive value of potatoes. Min. Tec. Bul. 196.
12. Ng, Keng Chock, H. D. Brown, R. H. Blackmore and John Bushnell, 1957. The relation of the calcium content of potato tubers to the quality of potato chips. Food Technol. XI: 118-122.
13. Schwimmer, Sigmund, Arthur Bevenue, William J. Weston, and A. L. Potter, 1954. Potato composition survey of major and minor sugar and starch components of the white potato. Agr. Food Chem. 2: 1284-1290.
14. Sharma, M. K., D. R. Isleib and T. Dexter, 1958. Specific gravity of different zones within potato tubers. Am. Potato Jour. 35: 784-788.
15. Stuart, Neil W., and C. O. Appleman, 1935. Nitrogenous metabolism in Irish potatoes during storage. Md. Agr. Sta.. Bul. 372.
16. Talley, Eugene A., Faire Lyn Carter and William L. Porter, 1958. Determination of end point in extraction of free amino acids from potatoes. Agr. Food Chem. 8: 608-610.
17. Watt, Bernice K. and Annabel L. Merrill, 1950. Composition of foods raw, processed, prepared. U.S. Dept. Agr. Handbook No. 8.
18. Woodward, C. F. and E. A. Talley, 1953. Review of the nitrogenous constituents of the potato. Amer. Potato Jour. 30: 205-212.

*In the interest of brevity no attempt has been made to give credit to scientists who were first to discover pertinent concepts. However, in the annotated bibliographies accompanying some references the reader may be able to not only learn of original efforts, but may discover many facts omitted from this very brief paper. As this manuscript is being mailed the book entitled "Potato Processing" came to my desk. This book published by the Avi Publishing Company, Inc. includes an excellent chapter by Cline M. McCay entitled "The Nutritive Value of Potatoes."

BUY YOUR CERTIFIED SEED FROM THESE GROWERS

HAROLD A. BISHOP
142 Franklin Street
Dansville, New York
Katahdin and Sebago

NORMAN A. BOGESTAD FARMS, INC.
Donaldson, Minnesota
Pontiac, Irish Cobbler and Kennebec

BILL BORCHARDT CO.
P. O. Box 281
East Grand Forks, Minnesota
Irish Cobbler, Red Pontiac, Kennebec and Red LaSoda
Red River Valley, Minnesota and North Dakota grown

LUCIEN BOUCHARD
Frenchville, Maine
Kennebec, Foundation and Certified

G. L. BRIDGEFORD & SON
R.F.D. # 2
East Grand Forks, Minnesota
Irish Cobbler and Red Pontiac

MONROE BROWN & SONS, *Foundation Growers*
Williams, Minnesota
Red Pontiac, Kennebec, Russet Burbank, Chippewa, Norland and Early Gem

CARTER SEED FARMS
Washburn, Maine
Irish Cobbler, Katahdin, Kennebec, Chippewa, Rural Russet, Pungo, Merrimack and Russet Burbank

ERNEST C. CHASSE
RFD #1
Madawaska, Maine
Katahdin, Kennebec, Green Mountain, Pungo and Red Progress

CLARK SEED FARMS
Richford, New York
Katahdin

DAVID D. DAIGLE
Fort Kent, Maine
Tuber Unit Kennebec and Tuber Unit Chippewa

ENGELSTAD BROTHERS
RFD #3
Thief River Falls, Minnesota
Red Pontiac, Red LaSoda, Early Ohio, Early Gem, Waseca and Norland

H. J. EVANS
Georgetown, New York
Kennebec, Katahdin and Sebago

H. C. GREENLAW LTD.
Millville, New Brunswick, Canada
Katahdin, Keswick, Sebago, Irish Cobbler and Pontiac

WESLEY F. HOLTMAN
1907 Third Street N.W.
East Grand Forks, Minnesota
Irish Cobbler, Early Ohio, Waseca, Red Pontiac and Kennebec

T. E. HOUGHTON & SONS
Fort Fairfield, Maine
Katahdin, Chippewa, Sebago, Plymouth, Pungo, Irish Cobbler, Kennebec and Green Mountain

MCDONALD & STARBUCK
Route #1
Monte Vista, Colorado
Red McClure, Russet Burbank and Blanca

NEW YORK POTATO GROWERS COOPERATIVE, INC.
P. O. Box 211
Bouckville, New York
Katahdin, Sebago, Kennebec, Plymouth and Chippewa

R. F. NORMAN & SON
RFD #1
Saranac Lake, New York
Green Mountain, Cherokee, Katahdin and Chippewa

NORTHERN SEED POTATO CO., LTD.
198 West Hastings Street
Vancouver 3, B. C., Canada
White Rose, Pontiac, Netted Gem, Kennebec and Red LaSoda

SYLVA D. OUELLETTE & SON
RFD #2
Fort Kent, Maine
Kennebec

PAUL H. PETRAN
Box 409
Albert Lea, Minnesota
Kennebec and Cherokee

BEN PICHA
Box 816
Grand Forks, North Dakota
Norland, Redkote and Kennebec

C. A. POWERS & CO.
133 Main Street
Fort Fairfield, Maine
Irish Cobbler, Kennebec, Katahdin, Chippewa, Pungo, Red Pontiac, Plymouth, Green Mountain, Sebago, Merrimack, Sequoia, Rural Russet, Russet Burbank, Bliss Triumph and Delus

LEON J. PRIBULA
Alvarado, Minnesota
Red Pontiac and Irish Cobbler

SMALLS' FARMS, INC.
Box 396
Kalispell, Montana
Russet Burbank, Certified and Foundation

J. D. SWAN, JR.
Turtle Valley Farms
Delavan, Wisconsin
Russet Burbank, Katahdin and Sebago

E. W. THOMPSON & SON
Box 82
Limestone, Maine
Cherokee, Kennebec and Katahdin

FORREST THOMPSON
Box 36
Baker, Minnesota
Red LaSoda, Red Pontiac and Irish Cobbler

THOMPSON FARMS
Clymer, New York
Plymouth, Katahdin, Kennebec, Merrimack, Saco, C. U. 1335 and Huron

PETER & HENTY VAN ERKEL
Box 126
Hollandale, Minnesota
Irish Cobbler, Red LaSoda and Kennebec

VERDOORN BROTHERS
Delavan, Minnesota
Irish Cobbler, Pontiac, Red LaSoda and Cherokee

BAGGING MACHINES

Lockwood Grader Corporation
Gering, Nebraska

The Trescott Company, Inc.
Fairport, New York

Troyer Manufacturing Company
Box 308
Smithville, Ohio

BAGS (Burlap)

Bemis Brothers Bag Co.
St. Louis 2, Missouri

Chase Bag Co.
Milwaukee, Wisconsin

Fulton Bag & Cotton Mills,
Minneapolis 13, Minnesota

BAGS (Paper)

Bemis Brothers Bag Co.
St. Louis 2, Missouri

Chase Bag Co.
Milwaukee, Wisconsin

Continental Can Company
Shellmar-Betner Flexible Packaging Div.
Mount Vernon, Ohio

Equitable Paper Bag Co.
Long Island City 1, New York

Oneida Paper Products
Clifton, New Jersey

BAGS (Polyethylene)

The Bakelite Company
30 East 42nd Street
New York 17, New York

Celanese Corp. of America
Plastics Division
290 Ferry Street
Newark 5, New Jersey

E. I. duPont de Nemours & Co., Inc.
Wilmington, Delaware

Equitable Paper Bag Co.
Long Island City 1, New York

BIN LOADERS

Troyer Manufacturing Company
Box 308
Smithville, Ohio

BIN UNLOADERS

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Box 308
Smithville, Ohio

BOXES

General Box Co.
1825 Miner Street
Des Plaines, Illinois and
Denville, New Jersey

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Box 308
Smithville, Ohio

BRUSHERS - DESPROUTERS

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Box 308
Smithville, Ohio

CAR FLOOR PADS

American Excelsior Corp.
1000 North Halsted Street
Chicago 22, Illinois

Jiffy Manufacturing Company
360 Florence Avenue
Hillside, New Jersey

CAR AND TRUCK HEATERS

Siebring Manufacturing Co.
George, Iowa

Western Metal Specialty Co.
North 62nd Street
Milwaukee, Wisconsin

CONVEYORS

John Bean Division
Lansing, Michigan

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Smithville, Ohio

CUTTERS (Seed)

K. G. Brown Manufacturing Co., Inc.
Mattituck, Long Island, New York

Lockwood Grader Corporation
Gering, Nebraska

Albert E. Trexler
P. O. Lenhartsville, Pennsylvania

Troyer Manufacturing Company
Box 308
Smithville, Ohio

DIGGERS

Deere & Co.
Moline, Illinois

International Harvester Co.
Harvester Building
Chicago, Illinois

Lockwood Grader Corporation
Gering, Nebraska

DRIERS

John Bean Division
Lansing, Michigan

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Smithville, Ohio

FUMIGANTS

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

FUNGICIDES

Chemical Insecticide Corporation
30 Whitman Avenue
Metuchen, New Jersey

E. I. duPont de Nemours & Co., Inc.
Wilmington, Delaware

Phelps Dodge Refining Corporation
300 Park Avenue
New York 22, New York

Rohm & Haas Company
Washington Square
Philadelphia 5, Pennsylvania

Stauffer Chemical Company
380 Madison Avenue
New York 14, New York

Tennessee Corporation
619 Grant Building
Atlanta 1, Georgia

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

U. S. Rubber Company
Naugatuck Chemical Division
Naugatuck, Connecticut

GRADERS & SORTERS

John Bean Division
Lansing, Michigan

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Box 308
Smithville, Ohio

HARVESTERS

Champion Corp.
Hammond, Indiana

Dual Manufacturing & Sales, Inc.
P. O. Box 5066
St. Paul 4, Minnesota

John Bean Division
Lansing, Michigan

Noffsinger Manufacturing Co.
Box 516, Greeley, Colorado

Paramount Manufacturing Co.
1615 East Main Street
Stockton, California

HERBICIDES

Chipman Chemical Co.
Bound Brook, New Jersey

Dow Chemical Co.
Midland, Michigan

General Chemical Division
Allied Chemical & Dye Corp.
40 Rector Street
New York 6, New York

Pennsylvania Salt Manufacturing Co.
of Washington
P. O. Box 1297
Tacoma, Washington

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

HORMONES

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

IRRIGATION EQUIPMENT

W. R. Ames Co.
150 Hooper Street
San Francisco 7, California

John Bean Division
Lansing Michigan

Buckner Mfg. Co. (Sprinklers)
Fresno, California

California Corrugated Culvert Co.
Berkeley 2, California

Champion Corporation
Hammond, Indiana

Chicago Metal Manufacturing Co.
Chicago 32, Illinois

Food Machinery & Chem. Corp.
Lakeland, Florida

Hale Fire Pump Co.
Conshohocken, Pennsylvania

March Automatic Irrigation Co.
Muskegon, Michigan

Olin Mathieson Chemical Corp.
Mathieson Building
Baltimore, Maryland

Moulton Irrigation Co.
Stillwater, Minnesota

R . M. Wade & Company
1919 N.W. Thurman Street
Portland 9, Oregon

INSECTICIDES

Chemagro Corporation
437 Fifth Avenue
New York 16, New York

Chemical Insecticide Corporation
30 Whitman Avenue
Metuchen, New Jersey

Geigy Agricultural Chemicals
Division of Geigy Chemical Corp.
P.O. Box 430
Yonkers, New York

Miller Chemical & Fertilizer Corporation
Baltimore, Maryland

Niagara Chemical Division
Middleport, New York

Phelps Dodge Refining Corporation
300 Park Avenue
New York 22, New York

Rohm & Haas Company
Washington Square
Philadelphia 5, Pennsylvania

Shell Chemical Corporation
460 Park Avenue
New York 22, New York

Stauffer Chemical Company
380 Madison Avenue
New York 17, New York

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

U. S. Rubber Company
Naugatuck Chemical Division
Naugatuck, Connecticut

Tennessee Corporation
Grant Building,
Atlanta 3, Georgia

PLANTERS

Deere & Co.
Moline, Illinois

Oliver Corporation
400 West Madison Street
Chicago 6, Illinois

International Harvester Co.
Harvester Building
Chicago, Illinois

RESPIRATORS (Dust Masks)

Farm Bureau Cooperative Association
254 North High Street
Columbus, Ohio

Mine Safety Appliances Co.
Braddock Avenue & Thomas Boulevard
Pittsburgh 8, Pennsylvania

Andrew Wilson Co.
Springfield, New Jersey

SEED

New York Potato Growers Coop., Inc.
Bouckville, New York

SEED TREATING EQUIPMENT

Paramount Manufacturing Co.
1615 East Main Street
Stockton, California

Troyer Manufacturing Company
Box 308
Smithville, Ohio

SPRAYERS & DUSTERS

John Bean Division
Lansing, Michigan

The Hardie Manufacturing Co.
Hudson, Michigan

F. E. Myers & Bro. Co.
249 Orange Street
Ashland, Ohio

Niagara Chemical Division
Food Machinery & Chemical Corp.
Middleport, New York

Troyer Manufacturing Company
Box 308
Smithville, Ohio

SPROUT INHIBITORS

General Chemical Division
Allied Chemical & Dye Corp.
40 Rector Street
New York 6, New York

Lockwood Grader Corporation
Gering, Nebraska

Naugatuck Chemical Company
Naugatuck, Connecticut

Sterwin Chemicals, Inc.
1450 Broadway
New York, New York

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

STONE PICKERS

Bridgeport Implement Works, Inc.
1483 Stratford Avenue
Stratford, Connecticut

John Deere
Moline, Illinois

TAGS

Dennison Manufacturing Company
Farmingham, Massachusetts

VINE & WEED KILLERS (Chemical)

Chemical Insecticide Corporation
30 Whitman Avenue
Metuchen, New Jersey

Chipman Chemical Co., Inc.
Bound Brook, New Jersey

The Dow Chemical Company
Midland, Michigan

E. I. duPont de Nemours & Co., Inc.
Wilmington, Delaware

Pennsylvania Salt Manufacturing Co.
1000 Widener Building
Philadelphia 7, Pennsylvania

Thompson Chemicals Corporation
3028 Locust Street
St. Louis 3, Missouri

VINE KILLERS (Mechanical)

Ford Motor Co., Tractor Division
Dearborne, Michigan

Lockwood Grader Corporation
Gering, Nebraska

WASHERS

Aeroglide Corporation
510 Glenwood Avenue
Raleigh 1, North Carolina

John Bean Division
Lansing, Michigan

Food Machinery & Chemical Corp.
Lakeland, Florida

Lockwood Grader Corporation
Gering, Nebraska

Troyer Manufacturing Company
Box 308
Smithville, Ohio

INDEX OF ADVERTISERS

University Microfilms
313 North 1st St
Ann Arbor Michigan

BULK RATE
U. S. POSTAGE
PAID
PERMIT No. 362
New Brunswick, N. J.